PEARSON

Science

STUDENT BOOK | 3RD EDITION

7

AUSTRALIAN CURRICULUM

PEARSON Science 7

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AUSTRALIAN CURRICULUM

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Pearson acknowledges the Traditional Custodians of the lands upon which the many schools throughout Australia are located.

We respect the living cultures of Aboriginal and Torres Strait Islander peoples and their ongoing connection to Country across lands, sky, seas, waterways and communities.

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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We acknowledge traditional Indigenous Knowledge systems are founded upon a logic that developed from Indigenous experience with the natural environment over thousands of years. This is in contrast to Western science, where the production of knowledge often takes place within specific disciplines. As a result, there are many cases where such disciplinary knowledge does not reflect Indigenous worldviews.

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Australian Curriculum
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Key

- Science inquiry skills
- Physical sciences
- Earth and space sciences
- Chemical sciences
- Biological sciences

How to use Pearson Science 3rd edition

Pearson Science components

Each Pearson Science 7–10 3rd edition 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 science inquiry 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 Society features to engage learners with real-world examples and to support differentiation
- topic summaries and end-of-topic glossaries.

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.

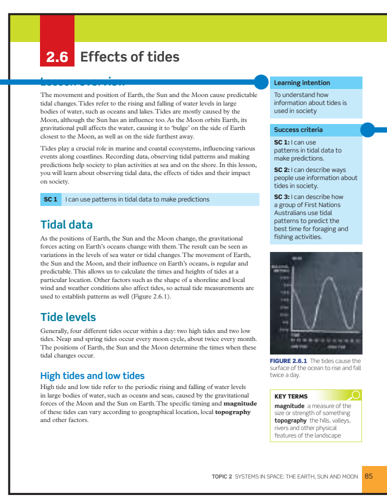
The Student Companion: a write-in workbook designed to reinforce the scaffolding of learning provided in the corresponding Pearson Digital Hub lessons. The Student Companion also supports the creation of a bound reference or portfolio of learning over the year.

Chunking with learning intentions and success criteria

The structure and relationship between each of the three components in the Pearson Science series (Pearson Digital Hub, the Student Book and the Student Companion) 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.

Across the three 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 Digital Hub has been developed around a single purpose for learning. The learning intentions are communicated using student-friendly language and are mirrored in each of the corresponding lessons in the Student Book and Student Companion. They describe what learners should know, understand or be able to do by the end of the lesson.



2.6 Effects of tides

The movement and position of Earth, the Sun and the Moon cause predictable tidal changes. Tides refer to the rising and falling of water levels in large bodies of water, such as oceans and lakes. Tides are mostly caused by the Moon, although the Sun has an influence too. As the Moon orbits Earth, its gravitational pull affects the water, causing it to 'bulge' on the side of Earth closest to the Moon, as well as on the side furthest away.

Tides play a crucial role in marine and coastal ecosystems, influencing various events along coastlines. Recording data, observing tidal patterns and making predictions help society to plan activities at sea and on the shore. In this lesson, you will learn about observing tidal data, the effects of tides and their impact on society.

SC 1 I can use patterns in tidal data to make predictions

Tidal data

As the positions of Earth, the Sun and the Moon change, the gravitational forces acting on Earth's oceans change with them. The result can be seen as variations in the levels of sea water or tidal changes. The movement of Earth, the Sun and the Moon, and their influence on Earth's oceans, is regular and predictable. This allows us to calculate the times and heights of tides at a particular location. Other factors such as the shape of a shoreline and local wind and weather conditions also affect tides, so actual tide measurements are used to establish patterns as well (Figure 2.6.1).

Tide levels

Generally, four different tides occur within a day: two high tides and two low tides. Neap and spring tides occur every moon cycle, about twice every month. The positions of Earth, the Sun and the Moon determine the times when these tidal changes occur.

High tides and low tides

High tide and low tide refer to the periodic rising and falling of water levels in large bodies of water, such as oceans and seas, caused by the gravitational forces of the Moon and the Sun on Earth. The specific timing and **magnitude** of these tides can vary according to geographical location, local **topography** and other factors.

Learning intention

To understand how information about tides is used in society

Success criteria

SC 1: I can use patterns in tidal data to make predictions.

SC 2: I can describe ways people use information about tides in society.

SC 3: I can describe how a group of First Nations Australians use tidal patterns to predict the best time for foraging and fishing activities.

FIGURE 2.6.1 The tides cause the surface of the ocean to rise and fall twice a day.

KEY TERMS

magnitude a measure of the size or strength of something

topography the hills, valleys, rivers and other physical features of the landscape

TOPIC 2 SYSTEMS IN SPACE: THE EARTH, SUN AND MOON 85

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 all three components – Pearson Digital Hub, the Student Book (and eBook) and the Student Companion – to ensure they are consistent throughout the lessons and to provide the basis for feedback.

Student book features

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

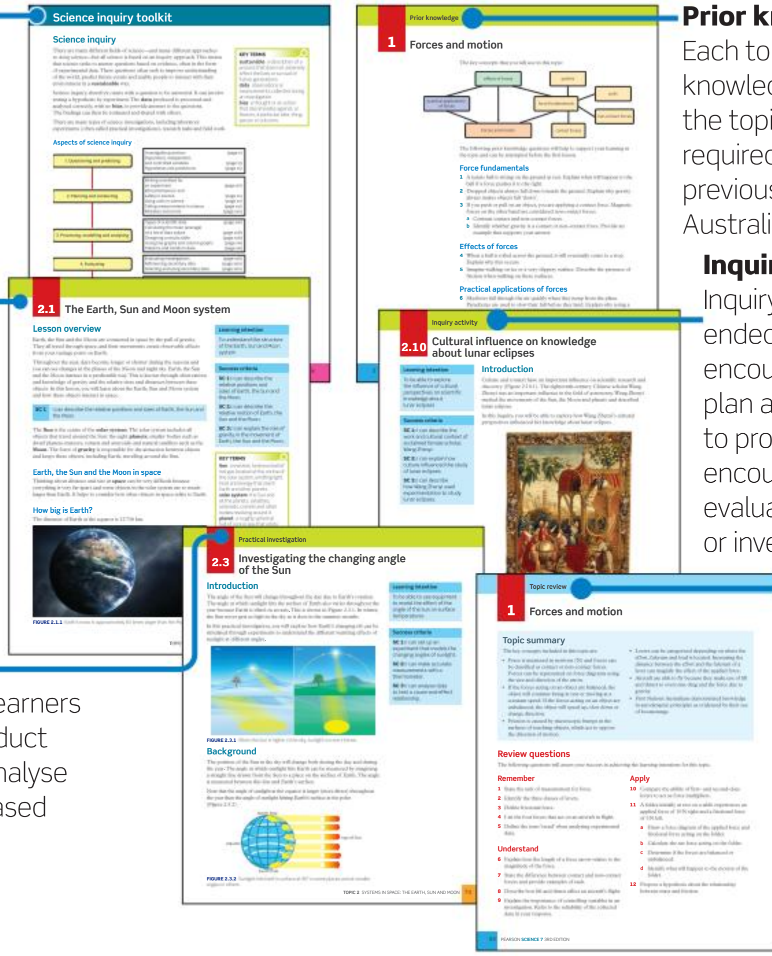
Prior knowledge lessons
Each topic begins with a prior knowledge lesson linking the topic key concepts to required knowledge from previous years or topics in the Australian Curriculum.

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.

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.

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

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.



Additional features

Hints

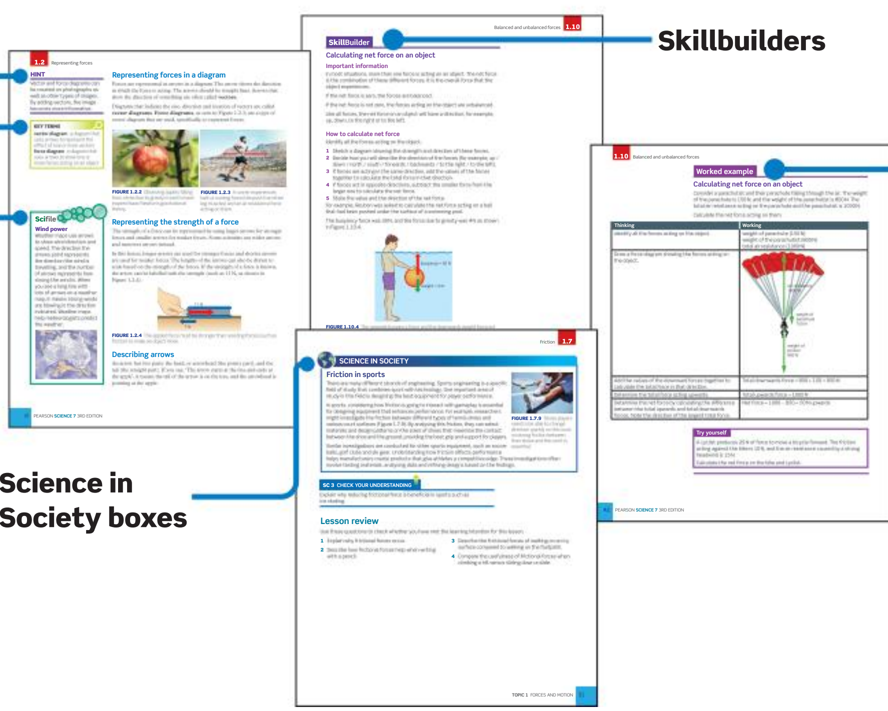
Key terms

Scifiles

Skillbuilders

Worked examples

Science in Society boxes



Science inquiry

There are many different fields of science—and many different approaches to *doing* science—but all science is based on an inquiry approach. This means that science seeks to answer questions based on evidence, often in the form of experimental data. These questions often seek to improve understanding of the world, predict future events and enable people to interact with their environment in a **sustainable** way.

Science inquiry, therefore, starts with a question to be answered. It can involve testing a hypothesis by experiment. The **data** produced is processed and analysed correctly, with no **bias**, to provide answers to the questions. The findings can then be evaluated and shared with others.

There are many types of science investigations, including laboratory experiments (often called practical investigations), research tasks and field work.

KEY TERMS

sustainable a description of a process that does not adversely affect the lives or survival of future generations

data observations or measurements collected during an investigation

bias a thought or an action that discriminates against, or favours, a particular idea, thing, person or outcome

Aspects of science inquiry

1. Questioning and predicting

2. Planning and conducting

3. Processing, modelling and analysing

4. Evaluating

5. Communicating

The information and activities in this Science Inquiry Toolkit will support your learning by describing, explaining and giving examples of science inquiry skills that you will use in Year 7. When carrying out practical investigations and inquiry activities, the knowledge and skills included in this toolkit will help you to succeed with the activities.

1 Questioning and predicting

1.1 Investigable 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.

TABLE 1 Types of investigable questions

Question type		Examples
Descriptive questions	These ask about facts or descriptions.	• *How long is the insect?* • *How many legs does the insect have?*
Relational questions	These compare things.	• *Which insect is the longest?* • *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?* • *Does the colour of the insect depend on the environment it lives in?*

KEY TERMS

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

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

Many science investigations seek to answer cause-and-effect questions as scientists seek to find out how certain things are affected by other **variables**.

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 (grip) between the tyres of a mountain bike and the ground. Table 2 shows the approach that he 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 can 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'.

1.2 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 1) 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 her 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.

The **dependent variable** is the growth of the plant, which she 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 (see Table 3 for a summary).

KEY TERMS

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

controlled variable a variable that is kept constant throughout an experiment

FIGURE 1 Many variables will affect the growth of these plants.

KEY TERMS

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

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

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	amount of sunlight received by each plant
Dependent variable	The variable that is being observed and measured in an investigation	height of plant
Controlled variables	The variables that are kept the same to ensure a fair (valid) investigation	• temperature of soil • type of soil • amount of water • size of pot

1.3 Hypotheses and predictions

Developing a hypothesis

KEY TERM

hypothesis a statement about the relationship between two variables, which can be tested experimentally

Scientists develop hypotheses to test ideas. A **hypothesis** suggests a link or relationship between an independent variable and a dependent variable. A hypothesis can be considered as a possible answer to the question that is being investigated. A hypothesis is called a 'testable hypothesis' if an investigation can be designed and carried out to see if the hypothesis is supported by results.

A hypothesis can be created by writing a sentence stating what will happen to the dependent variable when the independent variable is changed.

The following structures can be used to write a hypothesis.

<**this change**> in the <**independent variable**> will result in <**this change**> to the <**dependent variable**>.

Examples

A small increase in the **temperature** will result in **an increase** to the **growth** of a pea plant.

An increase in the **air pressure of a tyre** will result in **a decrease** to the **amount of friction on the road**.

Or:

If <**this happens to the independent variable**>, <**this will happen to the dependent variable**>.

Example

If **the temperature increases**, **the growth of the plants will increase**.

These structures will help you to create a hypothesis. The exact language used can vary, but make sure that the hypothesis does the following:

- It clearly states the independent variable. ☐
- It describes what change is being made to the independent variable. ☐
- It clearly states the dependent variable. ☐
- It describes how the dependent variable will change. ☐
- It can be answered with the materials, resources and time available to me. ☐

Testing a hypothesis

- If the results from an investigation match what the hypothesis stated, then the results support the hypothesis.
- If the results from the investigation do not match what the hypothesis stated, then the results do not support the hypothesis.

Making a prediction

To help to test a hypothesis, a **prediction** can be made about what could happen. A prediction describes what is expected to be observed when the independent variable in an investigation is changed.

An example of a prediction for the hypothesis above is:

After 7 days, the average height of pea plants that are grown at a temperature of 25°C will be taller than the average height of pea plants that are grown at a temperature of 20°C.

If the prediction is found to be correct, the hypothesis is supported. If what was predicted did not happen, the hypothesis is not supported. (Note that this does not necessarily mean that the hypothesis was wrong—further experiments may be required.)

Figure 2 summarises the processes that can be used to scientifically test an idea or answer a question.

KEY TERM

prediction a statement that suggests what will happen in an experiment, normally based on a hypothesis

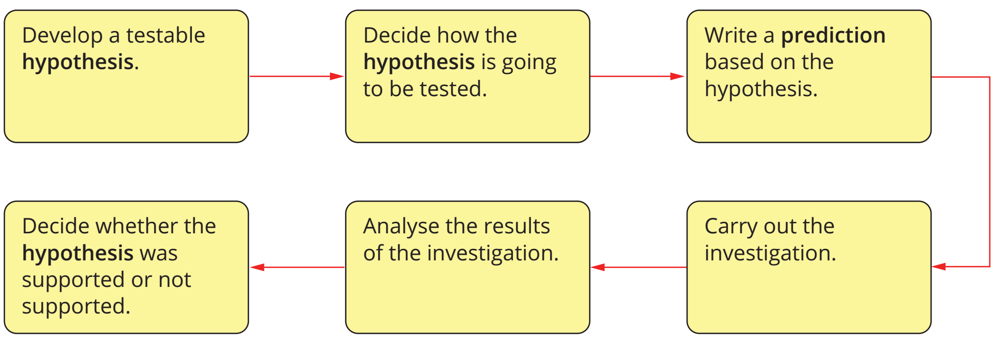


FIGURE 2 Testing a hypothesis

2 Planning and conducting

2.1 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 also helpful to include a diagram that shows how the experiment was set up.

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 of equipment and quantities of substances used.	☐
Include safety notes where required.	☐
Make it clear what observations and measurements are required and how they are to be recorded.	☐
Check that your materials list includes everything required in the method.	☐

Example

Kylie is planning an experiment to investigate the effect of sunlight on seedling growth. Her hypothesis is that sunlight will increase the rate of growth of seedlings. 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 soil and water 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.

She always clearly states how much water is used.

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 and a mask 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 for day 0.
6. Measure the height of the plants in the same way 2 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 2 days for the next 10 days, keeping the plants in the same position to maintain lighting conditions.

Safety notes

Make sure that gloves and a mask are worn when handling potting mix, as it may contain harmful microbes.

Materials

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

2.2 Ethical behaviour and safety in science

The following are key ethical considerations that need to be considered when carrying out science inquiries.

Science investigations should not cause harm

Some investigations have risks associated with them, which you need to consider and manage.

It is the responsibility of the person designing the investigation to ensure the method is a safe one. When you are conducting the investigation, it is your responsibility to ensure your own safety and those around you (Figure 3). Before starting any investigation, make sure you understand the safety rules and possible risks. This will enable you to reduce the chance of something going wrong and someone becoming injured.

FIGURE 3 Wearing eye protection, gloves, having hair tied back and following instructions carefully are examples of how to reduce the risk of harm in science investigations.

Science investigations should respect people's rights to make decisions

Anybody taking part in a science investigation should not only be physically safe, but they should not be asked to do anything that they are uncomfortable with. For example, many people will not want to be involved with an investigation that results in the death or harm to an animal or plant, and they should have the opportunity to not participate. Asking participants if they would like to be involved is an important part of this.

Science investigations should promote the good

The expected benefits of the science investigation should be greater than the risks, damage or financial or environmental cost of the investigation. Science investigations should result in better understandings of the world around us.

Science investigations should be fair

This does not just mean that the investigation is a fair test. It also means that there should be equal opportunities for people to be involved and the results of the investigation should made available to others. All work of others should also be acknowledged. This includes referencing the source of information used in the investigation (see Toolkit section 4.2).

2.3 Using units in science

The International System of Units, or SI units, is a standard way of measuring things and is used by scientists around the world. It's like a universal language for measurements based on seven base units. Some examples of these that you will use in science are shown in Table 4.

TABLE 4 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 grams (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 5).

TABLE 5 Examples of other common units used in science

SI base unit	Used to measure	Notes
degree celsius (°C)	temperature	based on the SI unit kelvin (K)
millilitre (mL)	volume	1000 mL = 1 litre (L)
newton (N)	force	named after Isaac Newton

2.4 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 **accurate** measuring device available. For example, to measure 6 mL of a liquid, do not use a 100 mL measuring cylinder. ☐
- Look straight at the measuring scale. Your eyes should be at right angles to the scale (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

KEY TERM

accurate how close the measured value is to the true value of the quantity that is being measured

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

error the difference between a measured result and the true value (see Toolkit section 2.5)

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 4, 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 curve. In this case the value measured would be 220 mL.

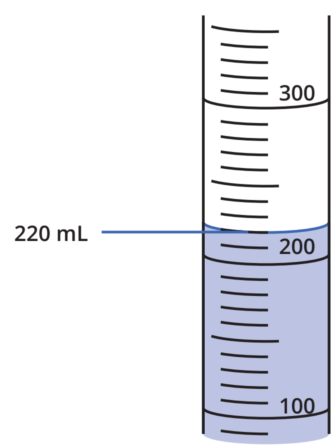


FIGURE 4 A measuring cylinder containing 220 mL of solution

Parallax error

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

Example

The three students look at the ruler from three different angles and each one reads a different measurement, between 18 cm and 22 cm (Figure 5).

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

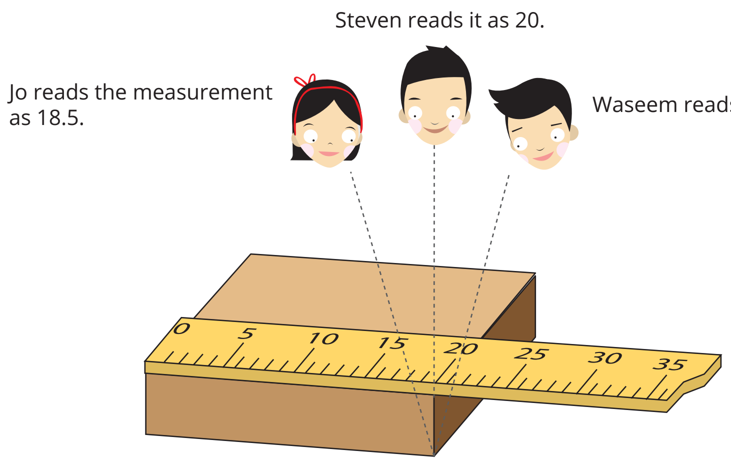


FIGURE 5 Parallax error is caused by taking the measurement from a different angle.

2.5 Mistakes and errors

Mistakes and errors are not the same thing.

Errors will always happen in science—they are 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.

TABLE 6 Types of experimental error

Type of error	Cause of error
Random errors are not the same every time.	They can be made worse by using equipment that is not accurate enough.
Systematic errors are similar each time the measurement is taken	They can be caused by an instrument that is not calibrated (set up or adjusted) correctly.

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.

3 Processing, modelling and analysing

3.1 Types of scientific data

Results that are collected during a science investigation can be either quantitative or qualitative data.

TABLE 7 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

3.2 Calculating the mean (average) of a set of data values

KEY TERMS

data set a set of results from an experiment

data value an individual result from an experiment

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**.

FIGURE 6 Force being measured with a newton meter

How to calculate mean (average) value

1. 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. She repeated the test four times (Figure 6).

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

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

Always remember to include a unit in your final answer.

3.3 Designing a results table

Results tables are important for the accurate recording of data. The following method can 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, 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.
- Give the table an informative title and figure number.

KEY TERM

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

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 8).

TABLE 8 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 the table has a title that includes the dependent and independent variables.

3.4 Using line graphs and column graphs

Line graphs

Line graphs 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.

KEY TERM

trend a pattern in data that changes in one direction

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 *x*- and *y*-axes drawn with a ruler?	☐
scales	Are the scales suitable, so the data fits on the graph?	☐
variables	Is the dependent variable on the vertical (*y*) axis?	☐
labels	Are the *x*- and *y*-axes labelled with the variable and the correct units?	☐
data	Is each data point correctly?	☐
line	Is there a line included that shows the pattern or trend in the data?	☐
title	Does the graph have a title that includes the dependent and independent variables?	☐

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 9.

TABLE 9 Force required to move sandbags of different mass across a 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 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 heart rate data range is 4.0–23.0, so the *y*-axis will need a suitable scale to fit this data.

Jack's graph could look like Figure 7.

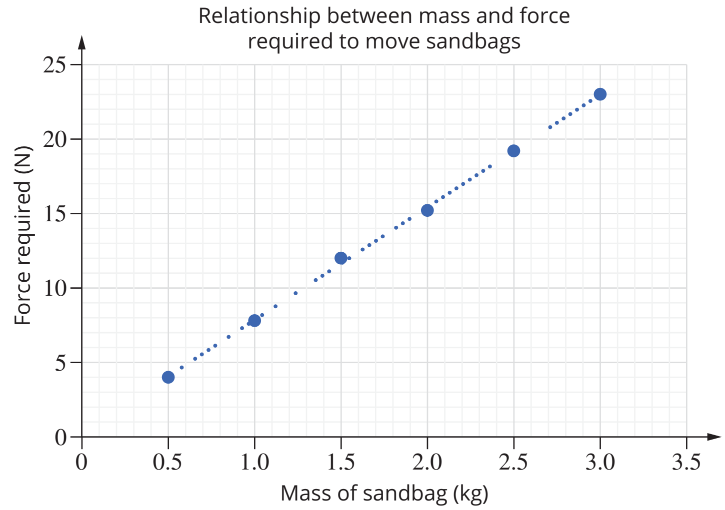


FIGURE 7 A line graph showing the relationship between force and the mass of sandbags

Column graphs

Column graphs 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 visited the most. She set up a webcam and recorded every instance of the appearance of the birds. Her results are shown in Table 10.

TABLE 10 Bird sightings between 2 pm and 5 pm on 3 July, 2024

Bird type	Number of sightings
magpie	4
honeyeater	7
pigeon	11
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 8. Note that she has used colour to make it easier to compare the three birds.

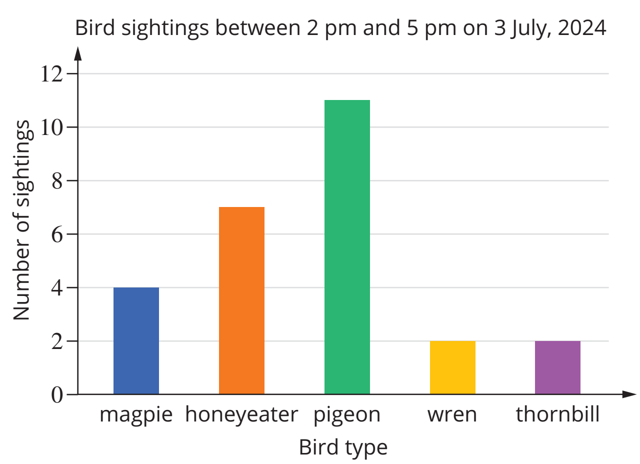


FIGURE 8 A column graph showing the number of sightings of each different bird type

3.5 Patterns and trends in data

A pattern is a repeated occurrence or sequence of results in data. Patterns can be used to predict observations. Patterns in data that you will come across in science include seasonal patterns, cyclical patterns and trends.

Seasonal patterns

A seasonal pattern is when data varies in a predictable way over a certain amount of time, such as a year, season, week or day.

For example, the average monthly temperature in one year in a certain place follows a seasonal pattern. Graphs can be used to identify and compare seasonal patterns for different places (Figure 9).

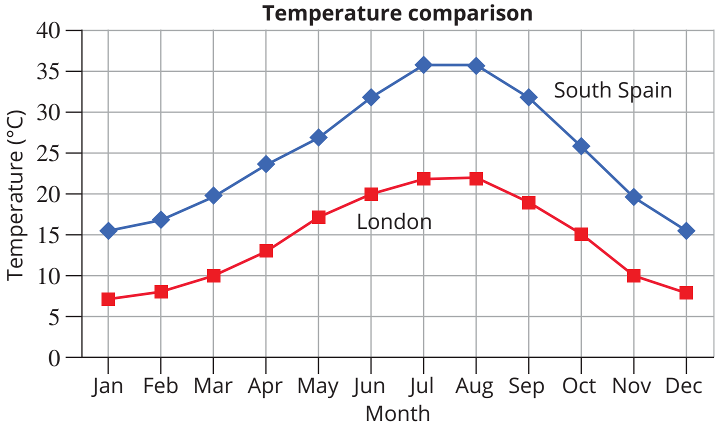


FIGURE 9 The seasonal variation of temperatures in two European locations

Cyclical patterns

A cyclical pattern occurs when the changes in the data repeat in a predictable way. Cyclical patterns are different from seasonal patterns because they are not directly linked to a fixed amount of time.

For example, the number of animals (the population) in an ecosystem may vary in a predictable way (Figure 10).

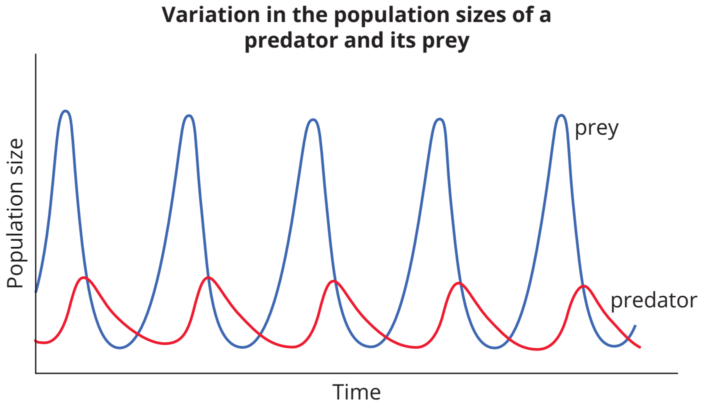


FIGURE 10 The cyclical variation in the population of a predator such as a sea eagle and its prey

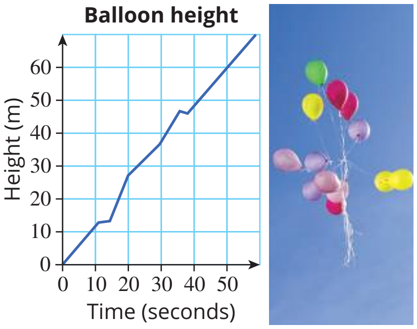


FIGURE 11 The height of the ballon is showing an upward trend.

KEY TERM

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

Trends

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 in Figure 11 is a trend because the balloon will keep rising.

4 Evaluating

4.1 Evaluating investigations

The aim of most investigations is to produce data that is used as **evidence** to support, or 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. Science investigations are evaluated by the quality of the data that they produce.

How to evaluate data from investigations

Data can be evaluated using the four main criteria shown in Table 11.

TABLE 11 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 measure 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 different models of toy car travel when pushed was repeated with the same force, 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 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 (e.g. 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.)	

4.2 Referencing secondary data

Secondary data is any information created by someone else (such as a book, website and 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, to ensure the data is not accidentally misrepresented or changed.

In an investigation or in research, remember to include the source of all secondary data used, and include an alphabetised list of your reference materials (called a reference list or **bibliography**) at the end of your report. These should be formatted in a consistent style and include all necessary information for another person to be able 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 Microsoft 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)
- name of the website (if different from the organisation name)
- webpage
- weblink.

Example

Sascha was investigating ecosystems and used information from the website Atlas of Living Australia to find out about bottlebrush plants (*Callistemon*) (Figure 12).

Sacha's reference is shown here. It includes the name of 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://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 authors, 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

KEY TERMS

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

bibliography a list of all sources of information that were used in a science inquiry

FIGURE 12 Bottlebrush plants (*Callistemon*) are native to Australia and found in many regions.

4.3 Selecting and using secondary data

When planning and conducting investigations, you will often need to do some research, which will involve identifying and using of secondary data.

When looking for resources, try to draw from a wide variety of source types, including books, websites, magazines/journals and videos (Table 12). However, the focus should always be on selecting the best resources for the task.

TABLE 12 Advantages and disadvantages of information sources

Type of resource	Advantages	Disadvantages
Book	• Information is easy to find through the table of contents and index. • Has been edited by an editor. • Is usually well researched and written by an expert.	• Information can be outdated. • Can take time to locate the exact information you require.
Website	• Provides access to a huge amount of information on the one topic. • 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. • Can be biased.
Video/ documentary	• Can provide first-hand accounts of events and situations. • Engaging and easy to watch.	• Can be difficult and time-consuming to find specific information. • May not be accurate and can be biased.

5 Communicating

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

Example

	Scientific writing	Non-scientific writing
Example 1	Sewage, which is wastewater from kitchens and bathrooms, can be recycled to make potable water suitable for human consumption.	Sewage which is wastewater from kitchens and bathrooms can be recycled but it is disgusting, and I would not drink it.
Example 2	Children were told the risks of using the Bunsen burner and importance of using exactly 5 cm of magnesium ribbon for the experiment.	The kids were told to watch it using the Bunsen burner and to get about 5 cm of magnesium ribbon for the experiment.

5.2 Scientific diagrams

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

Example

General drawings and diagrams (Figure 13 and 14)	• These are accurate representations reflecting shape, colour and proportions. • Labels, notes or a key can describe and identify features. • Arrows are used to show direction of processes (as Figure 13). • Arrows are not used to label parts and features.
Experiment report drawings (Figure 15)	• These are two-dimensional (2D) with carefully ruled lines, in correct proportions. (see also Toolkit section 5.3) • Equipment is labelled and connected to the object with a pointer line. • Labels are written in clear print.

Figures 13–15 demonstrate features of scientific diagrams and drawings.

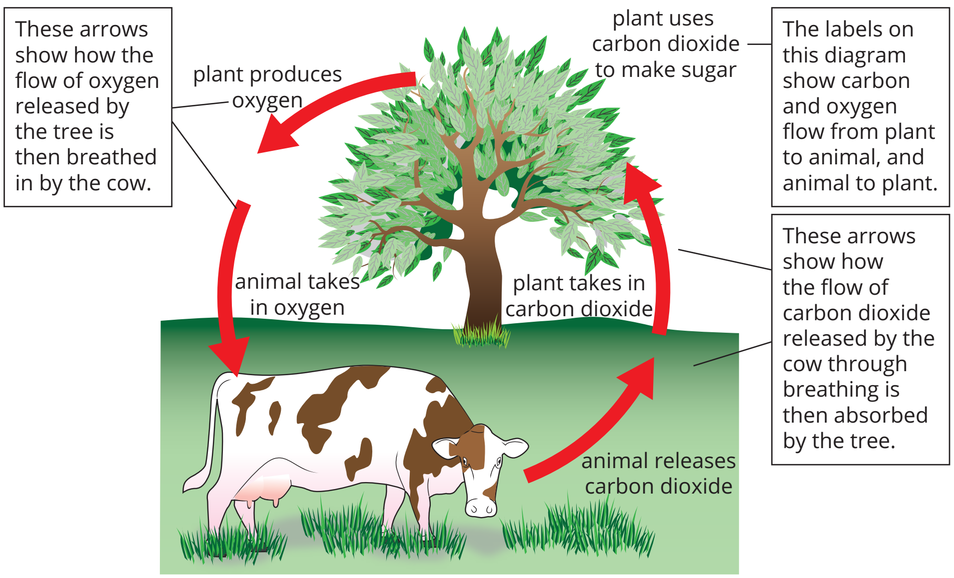


FIGURE 13 A diagram demonstrating the processes of the carbon cycle. It is simple and clearly labelled. The arrows identify the stages in the carbon cycle; different coloured arrows could be used to show movement of carbon dioxide and movement of oxygen.

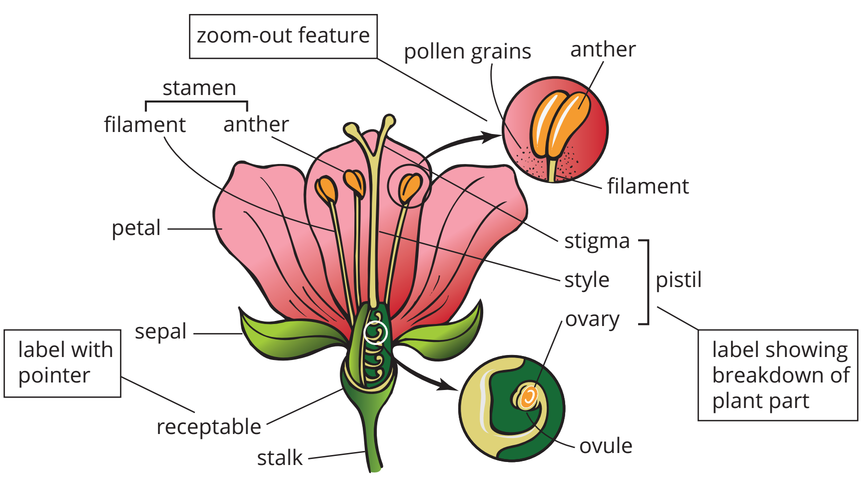


FIGURE 14 An accurate representation of the parts of a flower. Pointers are used to link to a zoom-out feature. All features are clearly labelled.

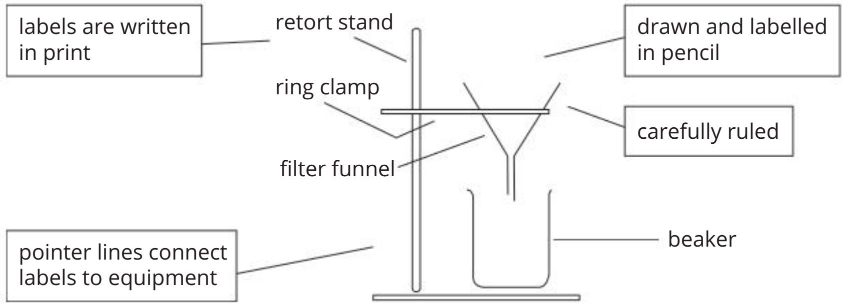


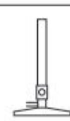
FIGURE 15 An example of a 2D diagram in an experiment report showing equipment set-up

5.3 Drawing scientific equipment

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

See Table 13 for examples of how to draw some common science equipment.

TABLE 13 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 2D style as a 'cross-section' (splitting the equipment down the middle).

These individual pieces of equipment can be combined to create an experimental set-up. The same style of diagram should be used to show the full set-up (Figure 16).

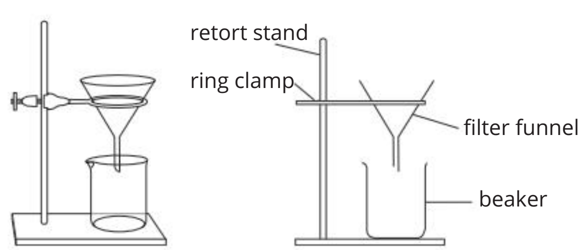


FIGURE 16 A scientific diagram showing a filtration experiment that uses a retort stand, a filter funnel, a ring clamp and a beaker

5.4 Graphic organisers

Graphic organisers are charts or diagrams that are used to help organise and present information or ideas. Graphic organisers can be very helpful for visual learners. There are several commonly used graphic organisers.

Flow charts

A flow chart uses boxes and words, as well as images, to demonstrate the sequence of events in a process or the way things are connected with each other (Figure 17).

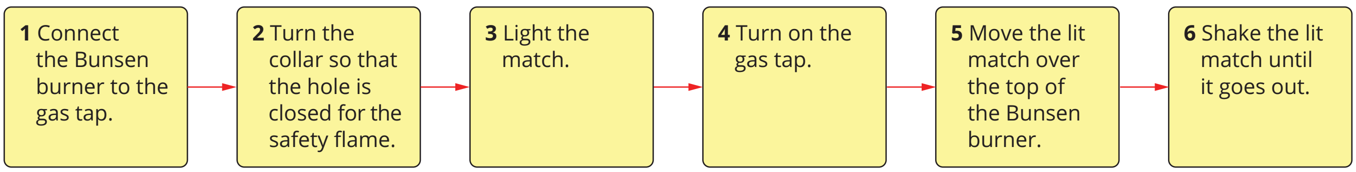


FIGURE 17 A flow chart showing the sequence for lighting a Bunsen burner

Concept maps

A concept map organises ideas in a **hierarchical** branching structure. It uses words and captions.

Ideas are linked by arrows. Ideas may also be linked with phrases such as 'leads to', 'results in' and 'impacts on'. The concept map in Figure 18 shows the relationships between water management and water shortage.

KEY TERM

hierarchical arranged in order of importance

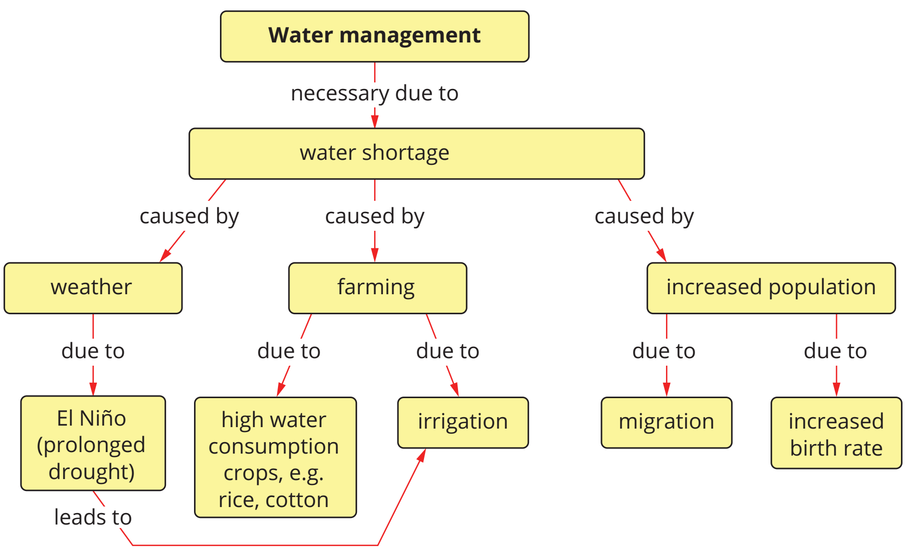


FIGURE 18 A concept map for the need for water management in an ecosystem

KEY TERM

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

5.5 Writing a practical investigation report

The **scientific method** helps scientists report on what they did, what happened and how their findings contribute to a better understanding of the subject. The reports you complete in class should aim to do the same thing. A report should include all the key aspects of the investigation, such as the aim, the hypothesis and/or prediction if required, a materials list, safety notes, the method used, results, a conclusion and often an evaluation of the method and the results obtained.

Investigation report

Reason for doing the investigation

Write a hypothesis, based on your aim. It can be written as an 'if..., then ...' statement. You can note all of the variables here.

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

Growing cress from seed

Aim

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

Hypothesis

If cress seeds are grown in a closed environment, then they will grow at a faster rate than when grown in an open environment.

- Independent variable: presence or absence of a lid
- Dependent variable: number of leaves on individual cress plants
- Controlled variables: type and size of containers, amount of water, nutrients or fertiliser in the water, age and number of seeds, how closely the seeds are planted. You might think of more.

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 leaves than 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.

Materials

- 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. Thirty cress seeds were spread evenly in each container.
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.

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

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												

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). Then your results will be more reliable.

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. This supports the hypothesis that cress seeds will grow more in a closed environment. This could be because the access to more oxygen reduces the rate of growth.

The conclusion relates back to the aim, and, if there is a hypothesis, whether the results from the experiment support the hypothesis. Suggested explanation for the findings can be included.

Evaluation

The results strongly supported the hypothesis because a 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. 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.

This can address questions such as:

- How well do the results support the hypothesis?
- Is there a reason for the results not being as expected?
- Were there any problems during the experiment?
- What did you do to overcome them?

Glossary

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

bias a thought or an action that discriminates against, or favours, a particular idea, thing, person or outcome

bibliography a list of all sources of information that were used in a science inquiry

continuous data quantitative data that can have any value

controlled variable a variable that is kept constant throughout an experiment

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 quantitative 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

hierarchical arranged in order of importance

hypothesis a statement about the relationship between two variables, which can be tested experimentally

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

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

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

prediction a statement that suggests what will happen in an experiment, normally based on a hypothesis

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

reliability how well repeated experiments, observations or measurements produce similar results

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

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

sustainable a description of a process that does not adversely affect the lives or survival of future generations

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

trend a pattern in data that changes in one direction

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 an object occupies

TOPIC 1

Forces and motion

Forces describe the interaction between objects. Usually, forces 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 their speed, change direction, stop or start moving.

Examples of forces are 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.

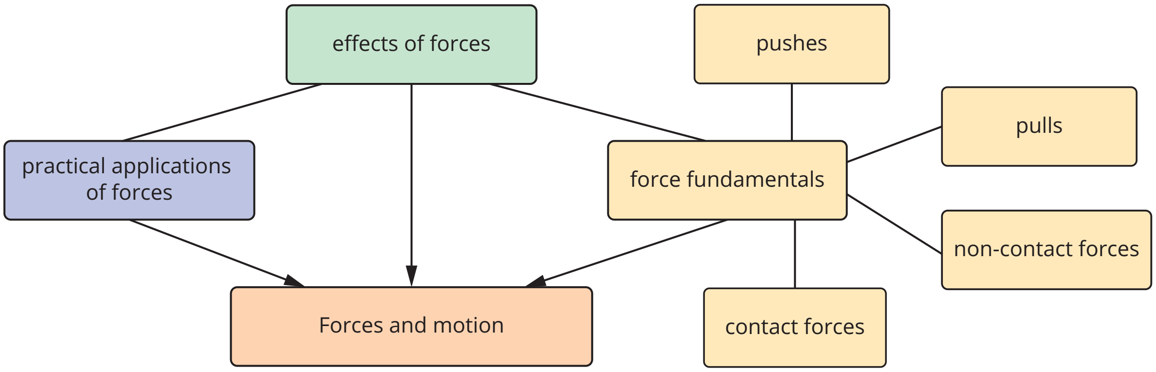
You will learn how forces can be used, measured and represented, and how to predict their effects.

Learning intentions

- [ ] To be able to describe the effect of forces on objects **3**
- [ ] To understand that arrows are used to show relationships between strength and direction of force **7**
- [ ] To be able to measure and record forces using the correct equipment and units **14**
- [ ] To be able to conduct reproducible investigations to answer questions and test predictions **17**
- [ ] To understand how levers can change the magnitude or direction of a force **20**
- [ ] To be able to analyse data to identify relationships **24**
- [ ] To understand the role of frictional force **27**
- [ ] To be able to investigate a relationship between friction and the mass of an object **32**
- [ ] To be able to conduct an investigation that analyses an aspect of friction **35**
- [ ] To understand that forces on an object can combine to result in balanced and unbalanced forces **39**
- [ ] To be able to explain how aeronautical engineers' understanding of forces has led to changes in aircraft design **46**
- [ ] To understand how cultural knowledge and understanding of the aerodynamic properties of boomerangs supported the conception of a vertical lift machine **49**

1 Forces and motion

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.

Force fundamentals

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 down towards the ground. Explain why gravity always makes objects fall 'down'.

3 If you push or pull on an object, 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 how these two forces act together to keep the kite in the air.

1.1 Forces in action

Introduction

There are many different types of forces that you see in action every day. Forces act in a variety of ways. 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 contact or 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, when you describe velocity, you must also include the direction the object is travelling in.

For example, you can say that the eagle in Figure 1.1.1 is flying at a speed of 5 m/s, or you can say that the bird has a velocity of 5 m/s travelling south.

Velocity as a vector quantity

A **vector** is something that has **magnitude** and direction. If its direction changes, the vector will change. Velocity, for example, is a vector quantity.

Consider this example. Satellites, such as the International Space Station (ISS) shown in Figure 1.1.2, orbit Earth at very high speeds. Although their speed stays the same, satellites in orbit around Earth have a velocity that is constantly changing as they move in a circular motion – their direction is constantly changing, so their velocity is constantly changing.

FIGURE 1.1.2 The ISS maintains an altitude of approximately 408 km above the surface of Earth, and has an orbital circumference of 42 650 km. While the speed of the ISS in its orbit is constant, its velocity is not.

Learning intention

To be able to describe the effect of forces on objects

Success criteria

SC 1: I can describe situations of acceleration, deceleration and constant velocity.

SC 2: I can define and give examples of contact and non-contact forces.

FIGURE 1.1.1 An eagle flying has both a speed and a velocity.

KEY TERMS

speed the rate of change of distance
velocity the speed and direction of an object
vector a quantity that has magnitude and direction
magnitude a measure of the size or strength of something

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 1.1.3) or drop something, it begins to accelerate. When a vehicle moves faster, it accelerates.

Deceleration

Deceleration is when an object is reducing in speed or velocity. Deceleration includes when an object stops moving. For example, when a bike hits a barrier, it decelerates really quickly (Figure 1.1.4).

FIGURE 1.1.3 The soccer ball is just about to accelerate towards the goal.

FIGURE 1.1.4 The bike decelerated very quickly!

KEY TERM

constant velocity the movement of an object at the same speed and in the same direction

Constant velocity

If the velocity of an object is not changing, it is described as having **constant velocity**. It is not decelerating or accelerating. It stays at the same speed travelling in the same direction. If an object stays exactly still, it has a constant velocity of zero.

If a table tennis ball remains exactly still in the flow of air from a hair dryer (Figure 1.1.5), it can be described as having zero velocity.

FIGURE 1.1.5 As a table tennis ball is light, only a small force is required to keep it in the air.

Aim

To observe a range of forces in action and to describe the effect of the forces using correct scientific language

Materials

- lump of modelling clay
- 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

SAFETY NOTES

- Follow the instructions for each task carefully.
- Turn the hair dryer off after use so it does not overheat.
- Ensure the water from the bucket does not create a slip hazard.
- Keep water away from electrical appliances.

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 following table 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 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.		
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 a stream of warm air directed upwards from a hair dryer.		

Conclusion

As observed in this investigation, forces can be categorised into contact forces, where the objects must touch to apply the force, or non-contact forces where the objects do not need to touch.

Some common contact and non-contact forces are included in Table 1.1.1.

TABLE 1.1.1 Examples of contact and non-contact forces

Contact	Non-contact
Frictional force Air resistance force Applied force Spring force	Gravitational force Electromagnetic force Nuclear force

Remember that forces may change the shape, speed or direction of travel of an object.

Write your conclusion to the experiment and include answers to the following.

Review the 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 contact forces that you observed in action
- **g** all the non-contact forces that you observed in action.

1.2 Representing forces

Lesson overview

Forces act all around you.

They can have different directions and strengths and, 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 toward 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 (Figure 1.2.1) to represent forces. This will help you understand which forces are acting and predict their effects.

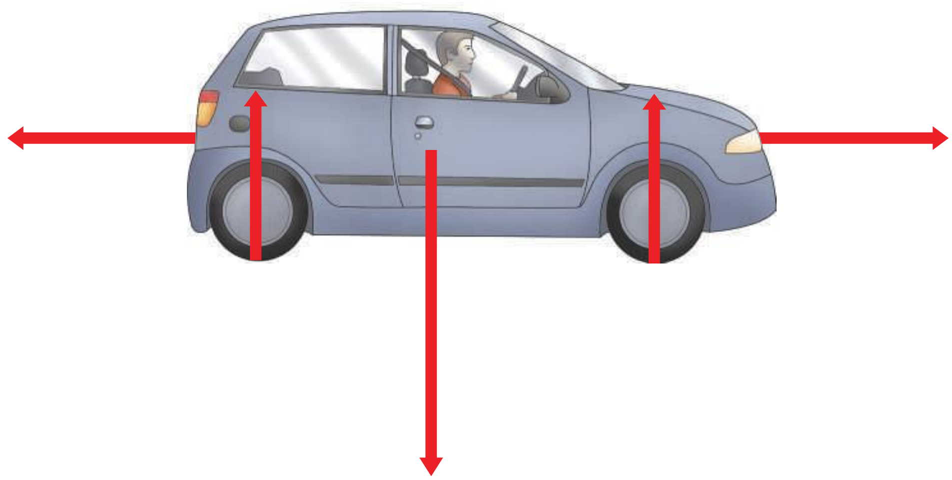


FIGURE 1.2.1 There are lots of different forces acting on this car.

SC 1 I can use a ruler to draw force arrows of different lengths to represent the magnitude of a force

Representing the magnitude of a force

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.

Measuring the strength of a force

The strength of forces is measured in **newtons** (N). This unit is named after the English scientist Isaac Newton. Newton was one of the first scientists to consider the idea of gravity as a force, and he also developed a range of laws that linked forces to the motion of objects (Figure 1.2.2).

Learning intention

To understand that arrows are used to show relationships between strength and direction of force

Success criteria

SC 1: I can use a ruler to draw force arrows of different lengths to represent the magnitude of a force.

SC 2: I can draw force arrows in the direction of the force relative to a direction convention.

SC 3: I can position force arrows correctly on a diagram, with the tail of the arrow at the point of contact, or at the centre of the object for non-contact forces.

KEY TERMS

force any interaction that will change the motion of an object when unopposed; for example, a push or a pull

newton (N) the unit used to measure force

HINT

Vector and force diagrams can be created on photographs as well as other types of images. By adding vectors, the image becomes more informative.

KEY TERMS

vector diagram a diagram that uses arrows to represent the effect of one or more vectors

force diagram a diagram that uses arrows to show one or more forces acting on an object

Representing forces in a diagram

Forces are represented as arrows in a diagram. The arrow shows the direction in which the force is acting. The arrows should be straight lines. Arrows that show the direction of something are often called **vectors.**

Diagrams that indicate the size, direction and location of vectors are called **vector diagrams**. **Force diagrams**, as seen in Figure 1.2.3, are a type of vector diagram that are used, specifically, to represent forces.

FIGURE 1.2.2 Observing apples falling from a tree due to gravity is said to have inspired Isaac Newton's gravitational theory.

FIGURE 1.2.3 A runner experiences both a running force (the push from their leg muscles) and an air resistance force acting on them.

Representing the strength of a force

The strength of a force can be represented by using larger arrows for stronger forces and smaller arrows for weaker forces. Some scientists use wider arrows and narrower arrows instead.

In this lesson, longer arrows are used for stronger forces and shorter arrows are used for weaker forces. The lengths of the arrows can also be drawn to scale based on the strength of the forces. If the strength of a force is known, the arrow can be labelled with the strength (such as 11 N, as shown in Figure 1.2.4).

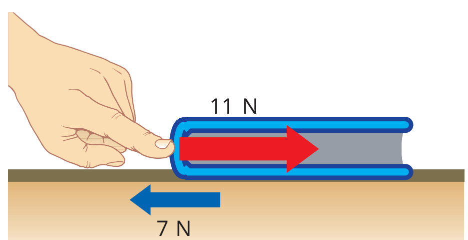


FIGURE 1.2.4 The applied force must be stronger than resisting forces (such as friction) to make an object move.

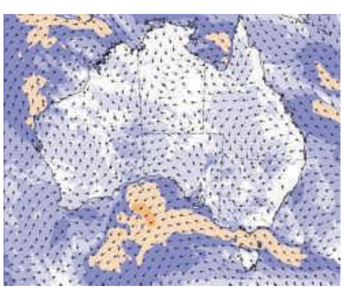
Describing arrows

An arrow has two parts: the head, or arrowhead (the pointy part), and the tail (the straight part). If you say, 'The arrow starts at the tree and ends at the apple', it means the tail of the arrow is on the tree, and the arrowhead is pointing at the apple.

Scifile

Wind power

Weather maps use arrows to show wind direction and speed. The direction the arrows point represents the direction the wind is travelling, and the number of arrows represents how strong the wind is. When you see a long line with lots of arrows on a weather map, it means strong winds are blowing in the direction indicated. Weather maps help meteorologists predict the weather.

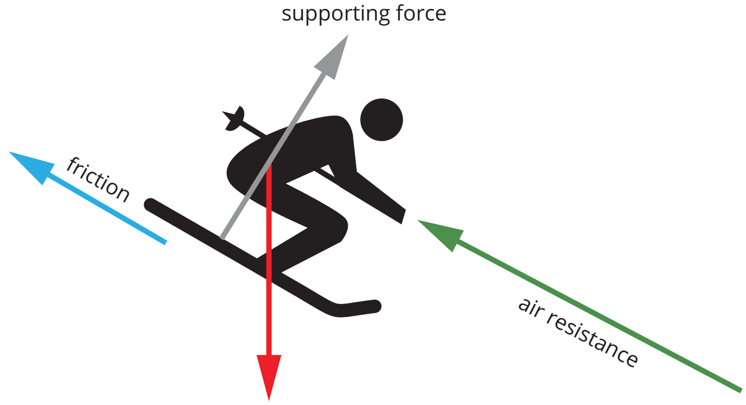


SkillBuilder

Drawing a force diagram

1. Identify the object 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.

For 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 and 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.



Worked example

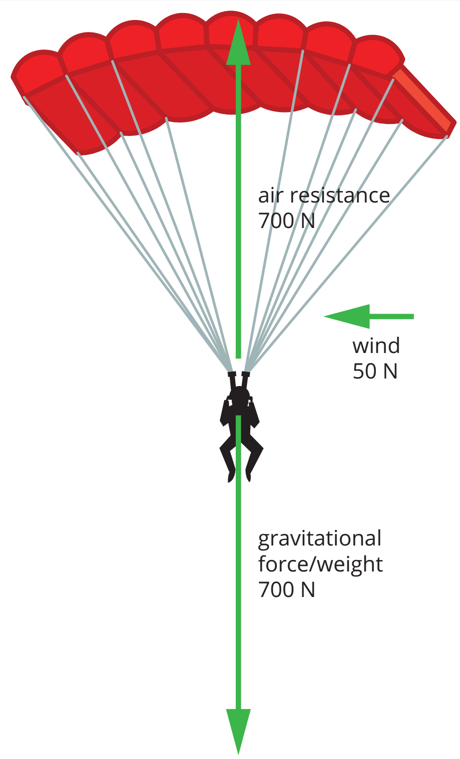
Drawing a force diagram

Problem

Use the following information to draw a force diagram that shows the forces acting on a parachute.

Geronimo was descending using a parachute. The gravitational force acting is 700 N, the air resistance against the parachute is 700 N and there is a side wind blowing from the right to the left, which is giving a horizontal force of 50 N.

Solution

Thinking	Working
What are the forces and in what direction are they acting on the parachute?	gravitational force (weight) (down) air resistance (up) wind (from the right side)
Are the values of each force different or the same?	The gravitational force and the air resistance are both the same (700 N), so the arrows representing these forces should be the same length. The wind force is much smaller (50 N), so the arrow representing this force should be smaller than the other arrows.
Have all the forces acting on the parachute been included?	yes
Draw the force diagram.	

Try yourself

Use the following information to draw a force diagram that shows the forces acting on a car.

The weight (gravitational force) of a small car is 9000 N. The force of the engine driving the car forward is 400 N, the air resistance of the moving car is 250 N, the friction force slowing the car down is 90 N and the force of the road supporting the car is 9000 N.

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 draw force arrows in the direction of the force relative to a direction convention

Representing the direction of a force

If you have ever got lost trying to follow someone's directions, you will understand that directions can mean different things to different people. This means that when you show a direction, you need to be very clear, especially if the object is moving, such as the objects in Figure 1.2.5.

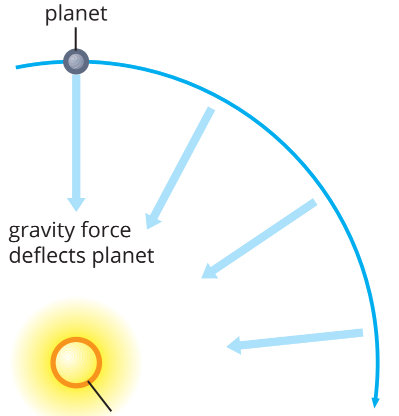


FIGURE 1.2.5 The direction of the force of gravity may change as an object moves; for example, as a planet orbits the Sun.

Points of reference

One way to make descriptions of directions clear is to use a **point of reference**. This is an example of a **scientific convention**. The point of reference is chosen, and all other directions are described relative to that position. For example, if the centre of Earth is used as the point of reference, forces can be described as away from, or towards, the centre of Earth.

KEY TERMS

point of reference something that is used for comparison

scientific convention an agreed way to carry out an action or communicate information

Points of the compass

Compass points are a common way to describe direction using a reference point. The main points of the compass are north, east, south and west as seen in Figure 1.2.6. North is the reference point and other directions can be described using words, such as south or north-west.

FIGURE 1.2.6 Compass points can be used to describe the direction of forces.

Right and left

Right and left seems an easy way to describe direction, but only if all observers are looking at something from the same direction. For example, if you go out of a room through a sliding door, you might slide the door to your left to open it, but if you turn around and come back into the room, you now slide to the door to your right. But the door is moving in the same direction each time! So be careful when using left and right.

Forwards and backwards

As with right and left, forwards and backwards can be used (see Figure 1.2.7 on the following page)—but you must make sure everyone is clear on which way is 'forwards' and which way is 'backwards'.

For example, you could use a wall as a reference point, so your observations would be 'away from the wall' or 'towards the wall.' This only works if there is only one wall though, so take your time when selecting your point of reference.

FIGURE 1.2.7 These Japanese bullet trains look the same going 'forwards' or 'backwards', which means using the words 'forwards' and 'backwards' to describe their movement is not the best system. A point of reference can be added, or a different system used.

Drawing force diagrams

When drawing force diagrams, ensure that the directions are clearly shown. For example, Figure 1.2.8 shows clearly the various forces acting on a truck driving on a road.

Note that the size of the arrows for the driving force and the friction force are the same length because they are the same strength (they are both 500 N).

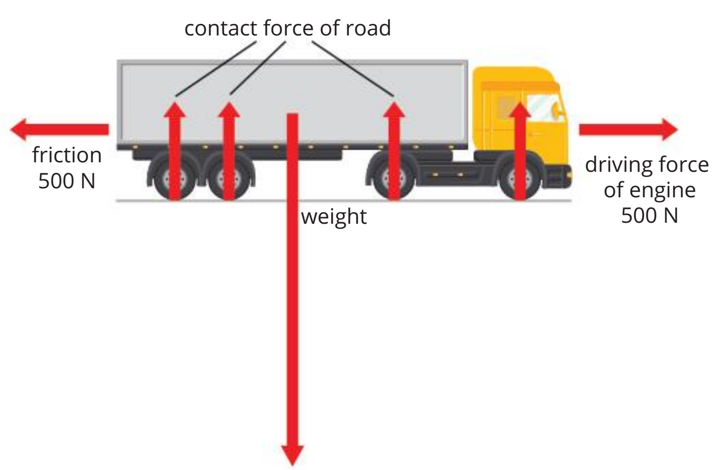


FIGURE 1.2.8 The forces acting on the truck are shown in four directions: to the right, to the left, upward, and downward.

GO TO
Toolkit section 5.2, Scientific diagrams

SC 2 CHECK YOUR UNDERSTANDING

Explain why a point of reference can be useful for describing the direction of forces.

SC 3 I can position force arrows correctly on a diagram, with the tail of the arrow at the point of contact, or at the centre of the object for non-contact forces

Drawing force arrows for contact and non-contact forces

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 1.2.9.

Non-contact forces

If a force is a **non-contact force**, the arrow should start at the centre of the object being affected, as shown in Figure 1.2.10.

Drag forces

Air resistance and the resistance of water are called **drag forces**. They are both contact forces, but because air is a gas and water is a liquid, it may be difficult to decide where to show the contact. In this case, you can start the arrow in the centre of the object, in the same way as for a non-contact force, or show the drag force in front of the object as shown in Figure 1.2.11.

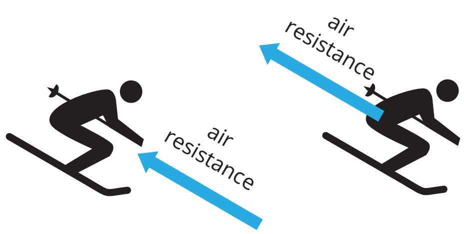


FIGURE 1.2.11 A skier experiences air resistance as their movement pushes air out of the way.

SC 3 CHECK YOUR UNDERSTANDING

Describe where the tail of a force arrow should be placed when drawing a contact force.

FIGURE 1.2.9 The wheels of a bike push along the ground, creating a contact force.

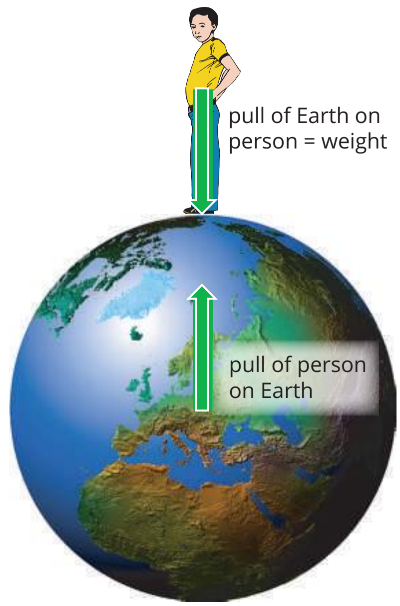


FIGURE 1.2.10 Gravitational forces are non-contact forces between objects that have mass.

KEY TERMS

contact force a force that acts between two objects that touch each other

non-contact force a force that acts on an object from a distance

drag force a force created by an object moving through a gas or liquid

Lesson review

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

1. Describe what is meant by 'direction convention' 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.

1.3 Measuring forces

Learning intention

To be able to measure and record forces using the correct equipment and units

Success criteria

SC 1: I can correctly use a newton meter to collect data.

SC 2: I can predict the amount of force required for a range of activities.

SC 3: I can consider ways to reduce error when measuring forces.

KEY TERMS

estimate an approximate judgement of the value or amount of time

newton meter a device used to measure the strength of a force; often called a spring balance

FIGURE 1.3.1 This spring balance measures up to 10 N.

SAFETY NOTE

- Ensure that the objects used in the experiment are not dropped or allowed to fall off benches or tables.

Introduction

Normally it is possible to **estimate** the strength of forces from how much effort you need to apply. Estimating is a valuable skill in science. For example, it can help you to predict the results of an experiment so that you can choose the correct equipment to use. In science, you should also know how to measure forces accurately so you can investigate the strength of different forces.

In this practical investigation, you will estimate the amount of force required to complete a range of tasks. You will then use a **newton meter** (also known as a spring balance, shown in Figure 1.3.1) to check your predictions. You will also consider how to improve the accuracy of your estimates and measurements.

Background

The unit of force is the newton (N).

A newton meter is an instrument that measures pulling forces. Newton meters have different measurement ranges for measuring different-sized forces.

Aim

To estimate and then measure the size of some common forces

Prediction

You will be predicting the strength of forces in this experiment. To help you, extend the newton meter to see what 1 N, 5 N and 10 N feel like. This will help you with your estimates later.

Materials

- newton meter (spring balance)
- 10 slotted 50 g masses and base/hook
- selection of items found in the laboratory or classroom (see the results table for suggestions)

Assessment of risk

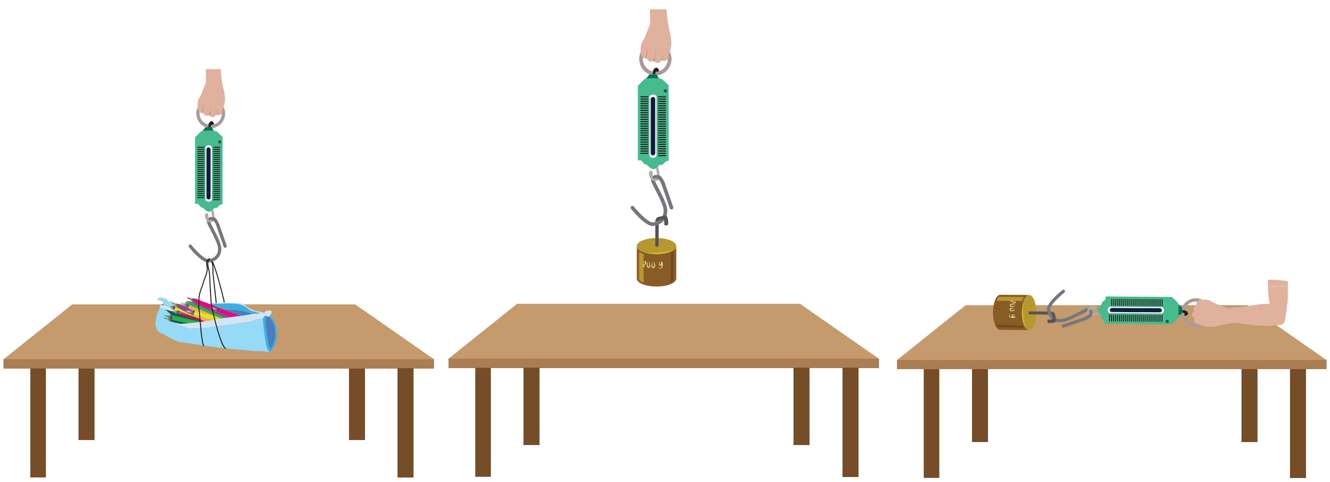
Ensure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

Method

1 Consider the results table. If some of these items are not available, use an alternative but similar item. You can also add some other items or tasks. Record all your measurements in the table as you work through the experiment.

2 Estimate the size of each force and record your estimate in the table. Then measure the force for each situation. Some possible set-ups for the measurement of the force are shown in the diagram.

GO TO
Toolkit section 2.4, Taking measurements in science



Results

Copy the following table into your notebook and use it to record your results.

Task	Estimate of size of force required (N)	Measured force (N)
pulling a pencil case along a bench		
lifting a test tube rack		
lifting a laptop lid		
unzipping a laptop bag or pencil case		
lifting a 100 g mass		
lifting a 200 g mass		
lifting a 300 g mass		
dragging a 300 g mass along a benchtop		

Conclusion

Write your conclusion to the experiment and include answers to the following.

1 How accurate were your estimates?

2 Suggest why you needed to use a larger force to lift the 300 g mass than to drag it along a benchtop.

3 Compare the force needed to lift the 100 g, 200 g and 300 g masses to the size of the masses.

4 Use your answer to question 3 to propose a relationship between the size of the mass and the force needed to lift it.

5 Use your answer to question 4 to predict the amount of force required to lift the following objects into the air:

   a 500 g mass

   b 60 kg person.

Evaluation

GO TO
Toolkit sections 2.5, Mistakes and errors and 4.1, Evaluating investigations

Evaluate your practical investigation. Include responses to the following.

1 Comment on how accurate your estimates were and suggest how you could improve the accuracy of your estimates.

2 Suggest how you could improve the accuracy of your measurements.

1.4 Investigating air resistance and gravity

Introduction

Gravity is the force that accelerates objects towards Earth. The greater the mass of an object, the greater the force of gravity acting on the object.

Air resistance is a force that acts to oppose the force of gravity as an object is falling. A spinning object can be designed to increase the air resistance it experiences. For example, a maple seed (Figure 1.4.1) has evolved to spin, causing it to take longer to fall to the ground. This gives the spinning object more chance of landing further away from the parent tree.

In this practical investigation, you will use a robocopter to investigate the effects of air resistance and gravity.

Background

Gravity is the non-contact force that pulls all objects towards Earth.

Air resistance is friction (a contact force) that occurs between an object and the air it passes through. Air resistance acts as an opposing force to gravitational pull. A spinning object can increase air resistance if it spins fast enough, with the surface area being effectively increased by the rotation of the object. Air resistance, being a type of friction, will oppose an object's motion.

Aim

To make a robocopter and then determine how changing one variable affects the time that it takes the robocopter to fall

Materials

- A4 sheets of light cardboard
- metre ruler
- pencil
- scissors
- stopwatch
- paperclips
- chair

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 conduct reproducible investigations to answer questions and test predictions

Success criteria

SC 1: I can follow a method to set up scientific equipment to conduct an investigation about gravity and air resistance that is reproducible.

SC 2: I can identify variables in an investigation.

SC 3: I can develop and test a prediction based on a falling object.

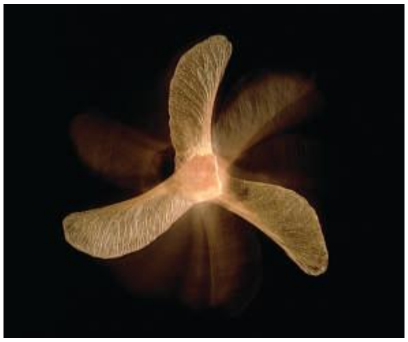


FIGURE 1.4.1 A maple seed spinning as it falls through the air

SAFETY NOTE

- Ensure that the person dropping the robocopter is safe and there is no risk of falling.

Method for preliminary trials

1 A template for a robocopter is shown in Figure 1.4.2, along with a diagram of the completed model.

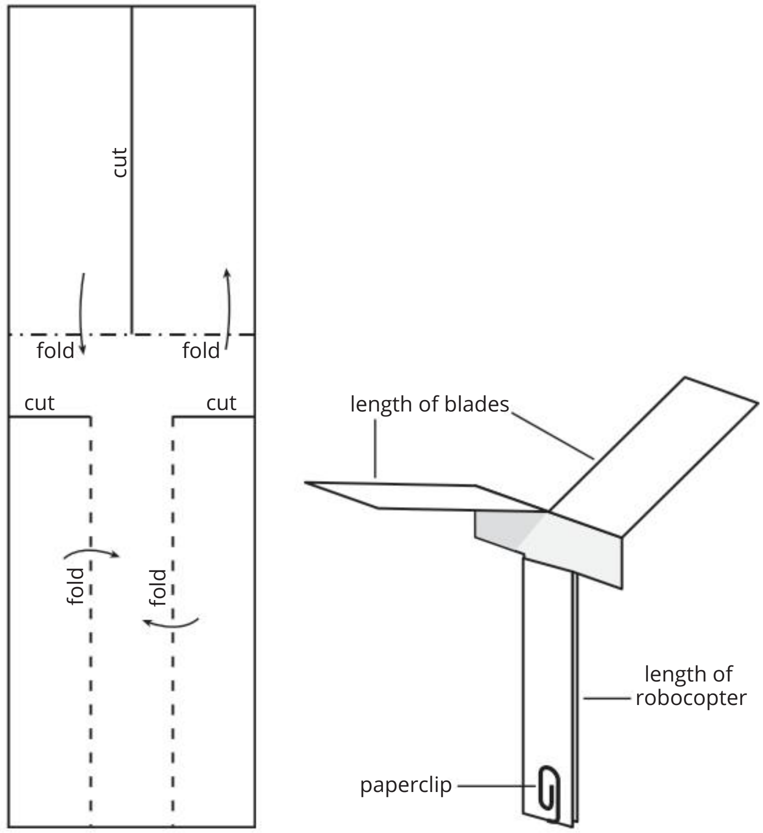


FIGURE 1.4.2 To build your robocopter, draw a copy of the template onto an A4 piece of light cardboard (cut lengthways).

2 Cut along solid lines and fold along dashed lines as shown by the arrows.

3 Place a paperclip at the base to complete the robocopter.

4 To conduct **preliminary trials** drop this robocopter from the same height three times. Measure how long it takes to fall to the ground in each case. Calculate an average time.

5 Construct a table to record the three times and the average.

GO TO
Toolkit sections 3.2, Calculating the mean (average) of a set of data values and 3.3, Designing a results table

KEY TERMS

preliminary trial a trial of an experiment used to test a method

Prediction

The time it takes for the robocopter to fall to the ground is the dependent variable in this investigation.

Now that you have tested the method, you can investigate what can affect the drop time of the robocopter.

First, decide which variable you will change. For example, you could:

- change the length of its blades
- add more paperclips to its base
- make different-sized robocopters
- make robocopters from different thicknesses of paper or cardboard.

GO TO
Toolkit sections 1.2, Dependent, independent and controlled variables and 1.3, Hypotheses and predictions

The variable that you chose to change is the independent variable for this investigation.

Once you have decided which variable you will change, predict what effect the change will have on the time it takes for the robocopter to reach the ground.

Method

Design a step-by-step method for your investigation that you will use to test your prediction. Explain how your investigation will be reproducible.

GO TO
Toolkit sections 2.1, Writing a method for an experiment and 3.3, Designing a results table

Results

Record your results in a table.

Conclusion

Write your conclusion to this experiment. Include answers to the following questions.

1 Name the dependent and the independent variable in your experiment.

2 How accurate was your prediction? Use evidence from your experiment in your answer.

3 Use your knowledge of forces to suggest a reason for your results.

1.5 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 describe real-life examples of first- and second-class levers being used as force multipliers.

SC 3: I can explain how levers change the magnitude of a force.

FIGURE 1.5.1 A pair of scissors is a simple machine.

KEY TERMS

lever a simple machine consisting of a rigid rod that pivots about a point
fulcrum the point about which a lever pivots
effort a force applied to a lever to overcome the load
load a force, often a weight, on a lever or material

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 1.5.1.

In this lesson you will learn about how different types of levers can help you to perform tasks more easily.

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, consider two forces:

- The input force which 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, as demonstrated in Figure 1.5.2, you can work out what type of lever it is.

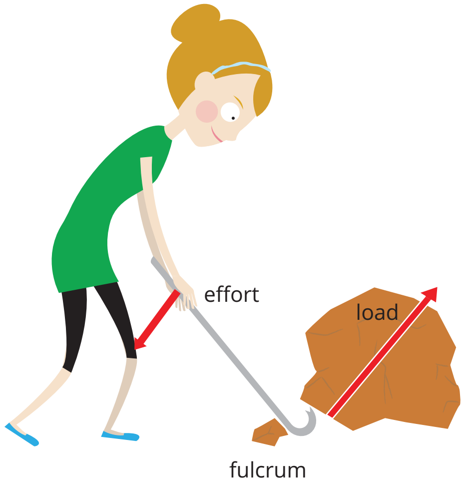


FIGURE 1.5.2 A crowbar acts as a lever; it increases the force you can supply, making it easier to move the rock (the load).

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 1.5.3.

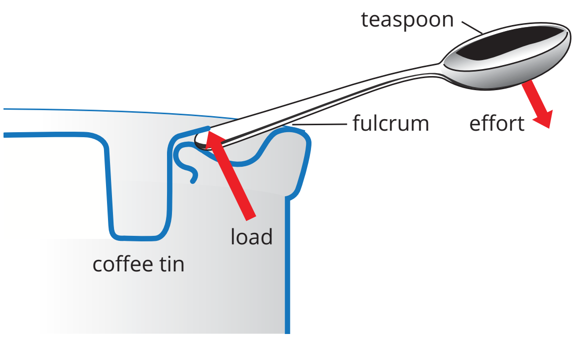


FIGURE 1.5.3 Using a spoon to open a coffee lid is an example of a first-class lever.

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 1.5.4.

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 1.5.5.

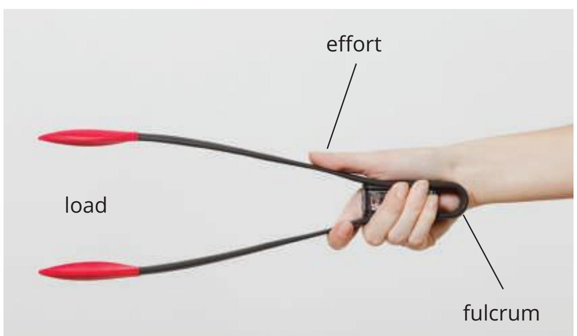


FIGURE 1.5.5 Tongs are a third-class lever as the fulcrum is the furthest point from the load.

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 describe real-life examples of first- and second-class levers being used as force multipliers

Many simple machines, such as levers, can increase the strength of an input force (the effort). These are called **force multipliers**.

KEY TERMS

first-class lever a lever with effort and loads at each end, and fulcrum in the centre

second-class lever a lever with the fulcrum at one end, the load in the centre, and the effort applied at the other end

third-class lever a lever with the fulcrum at one end, the effort in the centre, and the load at the other end

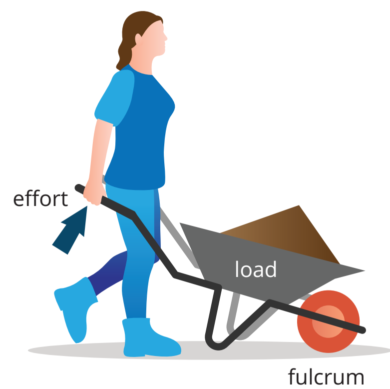


FIGURE 1.5.4 Wheelbarrows are a common example of second-class levers used to lift heavy loads.

HINTS

The positions of the fulcrum and the forces in the three types of levers can be remembered as:

Eif**fel** the **Elf Fel**l 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.

First-class levers as force multipliers

A first-class lever can act as a force multiplier by having the distance between the effort and the fulcrum greater than the distance between the load and the fulcrum. In this case, the person in Figure 1.5.6 pushing down on the plank can lift a heavy box. By applying the effort at a greater distance from the fulcrum, less force is required to move a heavy load.

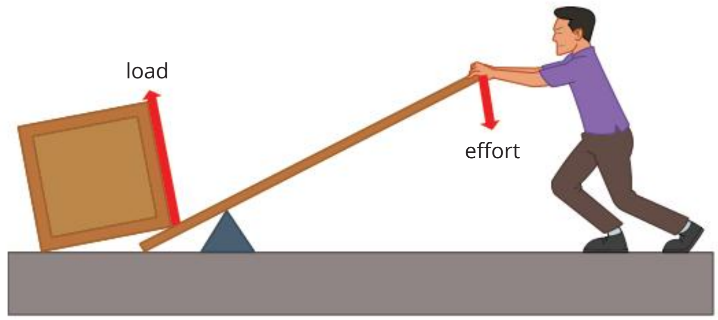


FIGURE 1.5.6 Increasing the distance between the effort and the fulcrum increases the force applied.

Scifile

See-saw science

A see-saw is an example of a first-class lever, as the fulcrum is between the effort (you) and the load (your friend). By sitting further away from the fulcrum while your friend sits closer to the fulcrum, you can lift a friend with less effort. On the other hand, as your friend is closer to the fulcrum than you are it will now take much more effort for your friend to lift you. It is a fun way to see how levers change the magnitude and direction of forces.

Second-class levers as force multipliers

All second-class levers are force multipliers as the effort is always further away from the fulcrum than the load, as seen in Figure 1.5.7.

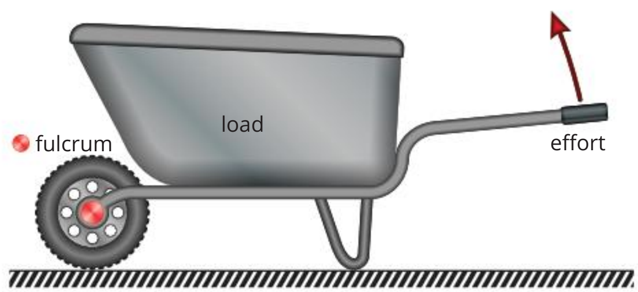


FIGURE 1.5.7 The handle of a wheelbarrow is further from the fulcrum than the load, making it a force multiplier.

SC 2 CHECK YOUR UNDERSTANDING

Describe how a first-class lever can be used as a force multiplier.

SC 3 I can explain how levers change the magnitude of a force

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 1.5.8—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.

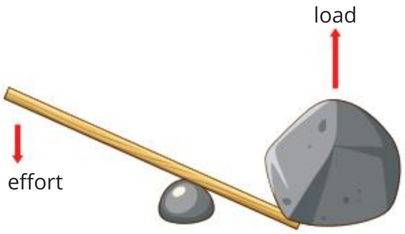


FIGURE 1.5.8 A weaker effort force applied at a greater distance will help move the heavy rock.

Second-class levers

All second-class levers are force multipliers since the effort is always further away from the fulcrum than the load. The longer the lever, in this case, the bottle opener, the easier it will be to open the bottle.

Note that in Figure 1.5.9, 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.

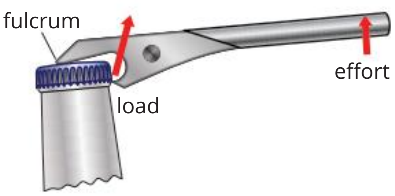


FIGURE 1.5.9 Bottle openers have long handles to open tight bottlecaps with ease.

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 3 CHECK YOUR UNDERSTANDING

Explain why a third-class lever can never be a force multiplier.

Lesson review

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

1 Explain how the position of the fulcrum, load and effort determines 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.

1.6 Investigating force and distance

Learning intention

To be able to analyse data to identify relationships

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 1.6.1 A small child can balance on a seesaw with an adult when the child sits further from the fulcrum than the adult.

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 moves further away from the fulcrum (Figure 1.6.1).

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 a first-class lever. 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

Materials

- 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.

HINT

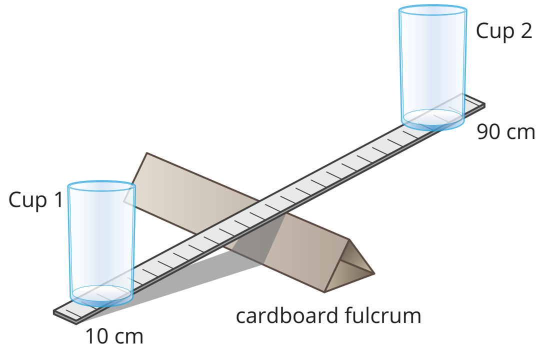
Before you begin, copy the results table below into your notebook. Alternatively, construct a spreadsheet with similar columns.

Method

1. Use scissors and a ruler to score two lines so the square piece of cardboard is divided into thirds. Bend the cardboard to make a triangular prism to use as a fulcrum, as shown in the diagram on page 25.
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.

4 Place Cup 2 on the other side of the seesaw, 40 cm from the fulcrum (this should 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.

7 Record the mass in Cup 2 in your results table or spreadsheet (column 4), and then empty Cup 2.

8 Move Cup 2 so that it is 33 cm from the fulcrum (this should be at the 83 cm mark).

9 Add masses to Cup 2 until the seesaw is balanced and record the total mass in Cup 2.

10 Repeat this process with Cup 2 at 25, 20 and 10 cm from the fulcrum (the 75, 70 and 60 cm marks).

HINTS

It can be very tricky to get the ruler to balance exactly.

If it will not exactly balance, get it as close as possible to balancing and record the total mass.

HINTS

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 halfway point of the ruler (50 cm mark).

Results

Copy the following table into your notebook and use it to record your results, or record your results in a spreadsheet.

1	2	3	4	5	6
Mass in Cup 1 (g)	Distance of Cup 1 from fulcrum (cm) [D_1]	Mass in Cup 1 × distance [D_1]	Mass in Cup 2 (g)	Distance of Cup 2 from fulcrum (cm) [D_2]	Mass in Cup 2 × distance [D_2]
50	40			40	
50	40			33	
50	40			25	
50	40			20	
50	40			10	

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.

GO TO
Toolkit section 4.1, Evaluating investigations

Evaluation

Suggest two improvements to how the data can be measured more accurately in this experiment.

1.7 Friction

Lesson overview

Friction is one force that is almost impossible to avoid. It will always occur between two surfaces that are in contact with each other. Sometimes you want to increase friction; for example, when riding a mountain bike on a slippery track. Other times you might want to reduce friction; for example, when trying to move fast across the surface of an ice rink (see Figure 1.7.1). In all situations, friction will act in the opposite direction to the motion of an object.

In this lesson, you will learn about where friction exists and to identify where you can use friction for your advantage.

Learning intention

To understand the role of frictional force

Success criteria

SC 1: I can define frictional force.

SC 2: I can describe everyday uses of frictional force.

SC 3: I can analyse different scenarios to determine if frictional force is useful.

FIGURE 1.7.1 Speed skaters will try to reduce friction once they are moving—but they need friction to get started.

SC 1 I can define frictional force

Rock climbing is a sport where climbers use **friction** to help them climb a wall or rockface. The holds on the wall are rough so climbers can grip them. Hands that get wet with sweat reduce the friction between the climber's hands and the holds, so chalk is used to absorb the sweat. Climbers can also wear climbing shoes with a special sole to increase the friction against the wall or rocks.

What is friction?

- Friction is a contact force that is always present when two surfaces are in contact with each other.
- It exists because bumps on two surfaces resist the movement of the touching surfaces as they slide past each other.
- There may also be some attractions between the chemicals that the surfaces are made from.

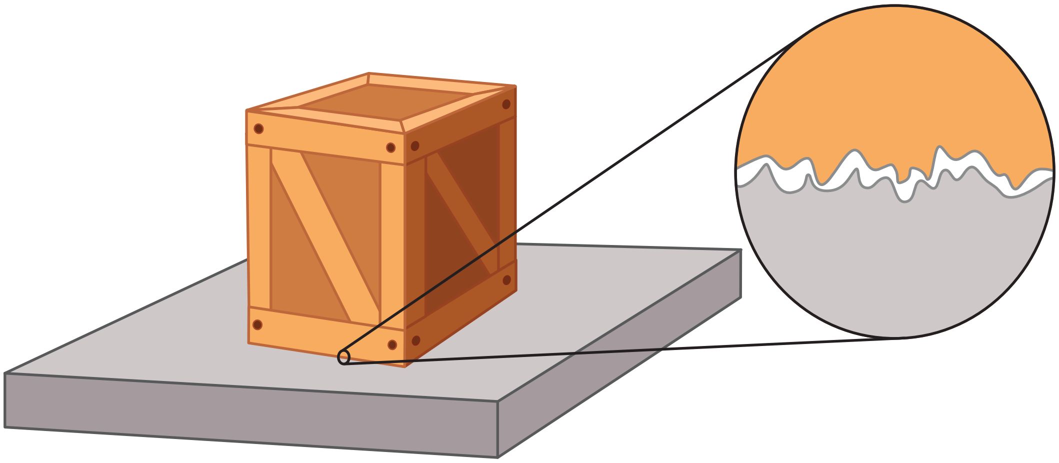


FIGURE 1.7.2 While it may look like the box and the ground have smooth surfaces, they are rough at a microscopic level.

The diagram in Figure 1.7.2 shows a close-up view of where the surface of the box is touching the floor surface. See how the bumps on the surfaces will slow or stop the box from moving over the floor.

KEY TERM

friction a force that acts against an object's motion

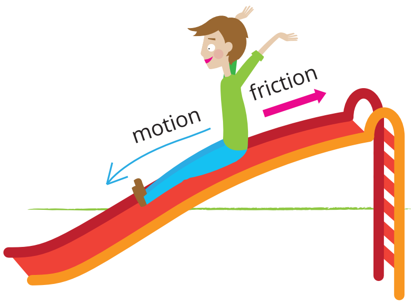


FIGURE 1.7.3 A person on a slide will experience friction that acts backwards on them as they move down the slide.

What direction does friction act in?

Friction will always act in the opposite direction to the movement of the object on a surface, as demonstrated in Figure 1.7.3.

SC 1 CHECK YOUR UNDERSTANDING

Describe the direction in which frictional forces always act.

SC 2 I can describe everyday uses of frictional force

The following pieces of equipment demonstrate how friction can be used in everyday life, including for bicycle tyres (Table 1.7.1), rock climbing equipment (Table 1.7.2) and bicycle brakes (Table 1.7.3).

TABLE 1.7.1 Understanding friction informs the design and choice of tyre treads

Mountain bike	Racing road bike
	
Tyres on a mountain bike are designed with a deep tread to maximise the interaction between the moving wheel of the bike and the rough surface of the trails.	Tyres on a racing road bike are quite smooth because the road's surface is smooth. Because the surfaces are similar, the area of contact between the two surfaces is maximised.

TABLE 1.7.2 Understanding friction informs the design and choice of shoes

Crampons	Rock climbing shoes
	
Climbers attach crampons to the soles of their shoes. The crampons can bite into the snow and ice, creating more friction. This allows the climber to grip on to the icy surface.	Rock climbing shoes are smooth. This gives them more contact surface with the rock. They are also made of a type of chemical that is slightly sticky, which increases the force between the shoe and the rock.

TABLE 1.7.3 Understanding friction informs the design of braking mechanism on bicyles

Rim brakes	Disc brakes
	
Traditional rim brakes on bikes work as the rubber block is pressed against the metal rim of the bike's wheel. This creates enough friction to slow the wheel down and stop the bike.	Disc brakes on bikes work as the block is pressed against the metal disc in the middle of the wheel. More friction force can be applied because the disc is flatter and presents more surface to the brake block than in a rim brake. The discs are also less likely to get wet or muddy than the rim of the bike wheel.

SC 2 CHECK YOUR UNDERSTANDING

Describe how frictional forces are used by bike brakes to slow a bike down.

SC 3 I can analyse different scenarios to determine if frictional force is useful

Friction will always oppose the motion of one surface moving across another surface. Sometimes this can help us, but sometimes the friction might not be useful.

Not-useful friction

If you want things to move fast, or for a long time, you would want to reduce friction. This can be done by reducing the surface area in contact between two objects or creating a slippery layer to separate two surfaces. Wheels are another method of reducing friction, as the wheels can roll over rough surfaces instead of sliding along them. This reduces the contact between rough edges and allows the wheels to move easily. The equipment shown in Figures 1.7.4–1.7.6 demonstrate how friction can be reduced when necessary.

Scifile

Smooth writing

When you write with a pencil, friction between the pencil tip and paper allows the graphite to leave marks. You can leave a darker mark with your pencil by increasing the friction between the tip and the paper, either by applying more pressure when writing or using a different type of paper with a rougher surface. Some pencils are also considered 'soft lead' pencils, because they leave more graphite behind with little friction. Without friction, writing or drawing would be a lot more challenging!

FIGURE 1.7.4 Using rolling objects such as wheels

FIGURE 1.7.5 Reducing the area of contact between the two surfaces, and sliding along a very smooth surface

FIGURE 1.7.6 Using a lubricant, such as oil or water, to reduce the friction

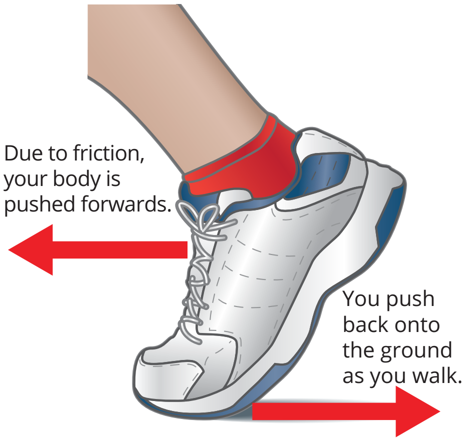


FIGURE 1.7.7 Shoes with rubber soles improve your ability to walk on surfaces by increasing friction.

Useful friction

There are many situations where friction is helpful.

Friction and shoes

An example where friction is helpful is with the grip of the soles of shoes. Your skeleton acts as a system of levers with muscles providing the force to move your body. When you walk or run, your leg muscles push your feet backwards. If your shoes grip the path, your feet stay in one place and the force from your muscles results in the leg and the body moving forwards, as demonstrated in Figure 1.7.7. If there was not enough friction, your feet would just slide backwards, and you would not move forwards.

Friction in nature

Many animals have evolved to have characteristics that maximise friction used to grip surfaces, which helps them survive. Geckos, like the one pictured in Figure 1.7.8, can climb on smooth surfaces.

Geckos' toes are covered in hundreds of hairs, and each hair contains many bristles. These hairs and bristles mean that the contact area between the feet and the surface is huge. The gecko can control the amount of friction by changing the angle of the hairs. If geckos suddenly want to move (and they can move very fast), they can switch the friction off by moving the hairs to reduce the amount of contact with the surface.

FIGURE 1.7.8 The hairs on a gecko's foot allow it to climb walls to seek shelter and hunt for prey.

SCIENCE IN SOCIETY

Friction in sports

There are many different strands of engineering. Sports engineering is a specific field of study that combines sport with technology. One important area of study in this field is designing the best equipment for player performance.

In sports, considering how friction is going to interact with gameplay is essential for designing equipment that enhances performance. For example, researchers might investigate the friction between different types of tennis shoes and various court surfaces (Figure 1.7.9). By analysing this friction, they can select materials and design patterns on the soles of shoes that maximise the contact between the shoe and the ground, providing the best grip and support for players.

FIGURE 1.7.9 Tennis players need to be able to change direction quickly on the court, so strong friction between their shoes and the court is essential.

Similar investigations are conducted for other sports equipment, such as soccer balls, golf clubs and ski gear. Understanding how friction affects performance helps manufacturers create products that give athletes a competitive edge. These investigations often involve testing materials, analysing data and refining designs based on the findings.

SC 3 CHECK YOUR UNDERSTANDING

Explain why reducing frictional force is beneficial in sports such as ice skating.

Lesson review

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

1 Explain why frictional forces occur.

2 Describe how frictional forces help when writing with a pencil.

3 Describe the frictional forces of walking on an icy surface compared to walking on the footpath.

4 Compare the usefulness of frictional forces when climbing a hill versus sliding down a slide.

1.8 Friction and mass

Learning intention

To be able to investigate a relationship between friction and the mass of an object

Success criteria

SC 1: I can propose a hypothesis and write a prediction based on the mass and the friction of an object.

SC 2: I can write a conclusion based on data from an experiment.

SC 3: I can evaluate the validity and reliability of the data from a practical investigation.

FIGURE 1.8.1 A newton meter can be used to measure how much force is required to slide this shoe across the ground.

GO TO
Toolkit section 1.3, Hypotheses and predictions

Introduction

There are many factors that will affect the friction in the situation shown in Figure 1.8.1; for example, the type of surface, the type of shoe, and whether the surface is wet or dry. But what about the mass of the shoe, or the mass of the person wearing the shoe?

This experiment allows you to answer questions such as these.

Background

Friction is a contact force that is always present when two surfaces are in contact with each other. It exists because bumps on two surfaces resist the movement of the touching surfaces as they slide past each other. The greater the mass of an object, the greater the force of gravity acting on that object, pulling it downwards onto the surface that it is resting on.

When conducting a scientific investigation, it is important that you consider the validity and reliability of the method.

A valid method means your investigation measures the intended variable accurately. To ensure validity, you should control as many variables as you can when collecting your data, so your independent variable is the only cause for any changes in your dependent variable.

To ensure reliability, you should have a method that can be easily repeated and will give similar results under similar conditions. If you are getting inconsistent data in an investigation, you should look at your method or equipment to see what can be improved to collect consistent data.

Aim

To investigate how increasing mass affects the size of friction

Hypothesis

Write a hypothesis for your investigation that answers the question: How does mass affect the amount of friction between two surfaces?

Materials

- wooden block with hook
- spring balance or force sensor
- 5 × 200 g masses

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

- The block may suddenly move, so take care to avoid getting your fingers squashed by the masses or the block. Masses may cause injury if dropped; for example, onto a foot.

Method

1 Copy the results table into your notebook. Alternatively, construct a spreadsheet with similar columns.

2 Place the wooden block on a benchtop.

3 Attach the spring balance to the block of wood, as shown in Figure 1.8.2.

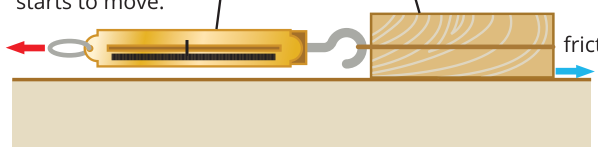


FIGURE 1.8.2 Ensure your spring balance is correctly attached to the block.

4 Measure the size of the force needed to keep the block moving at a constant speed. This is equal to the force of friction. Record this in your results table.

5 Repeat step 4 twice and record the results.

6 Add a 200 g mass on top of the block of wood. Measure the friction between the block and the benchtop three times and add these results to the table.

7 Repeat the friction measurements for 400 g, 600 g, 800 g and 1000 g (1 kg) masses on the block, recording three results for each test.

Results

Copy the following table into your notebook or in a spreadsheet and use it to record results.

Object moving	Friction force (N) measured on blocks of different mass			Average friction force (N)
	Trial 1	Trial 2	Trial 3	
wooden block				
wooden block + 200 g				
wooden block + 400 g				
wooden block + 600 g				
wooden block + 800 g				
wooden block + 1000 g				

GO TO
Toolkit sections 3.2, Calculating the mean (average) of a set of data values and 3.4, Using line graphs and column graphs

1. Calculate the average of your results in the table by adding the three forces and dividing by 3. Alternatively, program your spreadsheet to calculate the average for you.
2. Construct a line graph showing your results. Place 'Mass added to the block (g)' on the horizontal axis (0, 200, 400, 600, 800, 1000) and 'Average friction force (N)' on the vertical axis.

Conclusion

Write your conclusion to this experiment. Include answers to the following questions.

1. What happened to the size of the force of friction as the mass on the wooden block increased?
2. Describe a situation in which you have noticed this link between friction and mass.
3. Construct a conclusion for your investigation.
4. Assess whether your hypothesis was supported or not.

GO TO
Toolkit sections 3.5, Patterns and trends in data and 4.1, Evaluating investigations

Evaluation

1. Comment on the validity of your investigation.
2. Comment on the reliability of your investigation.

1.9 Investigating friction

Introduction

Friction is a contact force. Sometimes people aim to reduce friction; for example, to make a bike go faster. Sometimes people aim to increase friction; for example, to increase the grip of the brakes on the wheels or the grip of the tyres on the ground (Figure 1.9.1).

A range of factors, or variables, will increase or decrease the strength of the force of friction.

FIGURE 1.9.1 An increase in friction, due to the tread on the tyres, gives the rider more control when riding over different surfaces.

In this inquiry activity, you will construct a question around the strength of friction. You will design and conduct an investigation to answer that question. You will be given some guidance on which situation to use and the variable you are investigating.

Background

Finding the answers to questions is what science is all about. Questions can range from 'How will the climate change over the next 15 years?' to 'What type of tyre is the best to use on a mountain bike on wet trails?' and many, many more.

Before a scientist investigates anything, they normally start with an inquiry question like these. This question will define the investigation, so it is very important to ask the right question.

Checking your inquiry questions

If a question is not clear, the answer to the question may not be very helpful.

If a question is not able to be investigated, it might not even be possible to achieve an answer at all.

If a question is clear and can be investigated, it is called an investigable question.

Learning intention

To be able to conduct an investigation that analyses an aspect of friction

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 process and analyse results to develop a conclusion from primary data.

GO TO
Toolkit section 1.1, Investigable questions

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.

Two examples of an inquiry questions are shown in Table 1.9.1.

TABLE 1.9.1 Examples of how you might create an inquiry question based on your observations

	Example 1	Example 2
Observation	 Surfboards come in different shapes and sizes.	 The sole is the part of the shoe that connects to the ground when running.
Situation and variable	The situation is surfing, and the variable is the shape of the board.	The situation is running, and the variable is the size of the shoe.
Inquiry question	Does a surfboard go faster through the water if the shape of the board is changed?	Does a running shoe's friction increase as the shoe's size increases?

GO TO
Toolkit section 3.1, Types of scientific data

KEY TERM

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

These are both examples of questions about **cause-and-effect relationships**. In Question 1, the variable chosen to be investigated is qualitative because the shape of the board can be described but is not an amount or number. The variable chosen in Question 2 is quantitative because the size of the shoe can be measured.

Factors affecting friction

Several variables may affect the strength of friction between two surfaces. These include the size of the surfaces, the force pressing the surfaces together, the materials and roughness of the surfaces, the wetness of the surfaces or whether there are other materials between 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.

GO TO
Toolkit section 1.2, Dependent, independent and controlled variables

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 (spring balances) to directly measure the amount of force, or there are other indirect ways that the amount of friction can be compared.

GO TO
Toolkit section 2.4, Taking measurements in science

Controlled variables

To start designing your experiment, you will need to decide what the controlled variables will be. A controlled variable is a variable that is kept constant throughout the experiment.

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. If it is a quantitative variable, decide on the range of values you will use and how many trials you will use. You can also decide if you will need to repeat any of the trials.

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 materials that you will use and include a table for your results.

GO TO
Toolkit sections 2.1, Writing a method for an experiment and 3.3, Designing a results table

Prediction

Use your knowledge of friction and any other relevant observations to predict the result of your experiment. This is what you think the answer to your inquiry question is.

Conduct

Conduct your investigation according to 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.

GO TO

Toolkit section 3.2, Calculating the mean (average) of a set of data values

Record

Ensure that all data is recorded accurately in your results table.

Conclude

Write a conclusion using your experiment's results to answer your inquiry question. Include actual data from the experiment to support your ideas.

1.10 Balanced and unbalanced forces

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. Now that you have a good understanding of a range of different contact and non-contact forces, you can consider how these forces act as a combination. In particular, you can consider whether the forces are balanced or unbalanced, as this will have a huge effect on the movement of the object.

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.

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 vector 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.

SC 3: I can explain the concept of terminal velocity when forces are balanced.

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

balanced forces forces acting on a single object where the force in one direction is equal to the force applied in the opposite direction

SC 1 I can use vector diagrams to show balanced and unbalanced forces acting on objects

Forces can be represented with force diagrams that use arrows to show the direction and magnitude (strength) of forces acting on an object. These arrows are called vectors. Force diagrams are a type of vector diagram.

When more than one force is acting on an object, there will be multiple vectors shown in the force diagram. In Figure 1.10.1, there is a pushing force of 11 newtons (N) acting to the right and a friction force of 7 N acting to the left. These forces are **unbalanced forces** because the forces are different strengths.

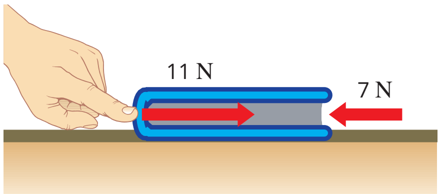


FIGURE 1.10.1 The unbalanced forces acting on the book will make it move across the table.

In Figure 1.10.2, 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.

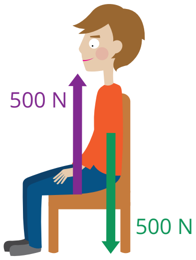


FIGURE 1.10.2 The balanced forces acting on the student means they will remain in the chair.

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 1.10.3.

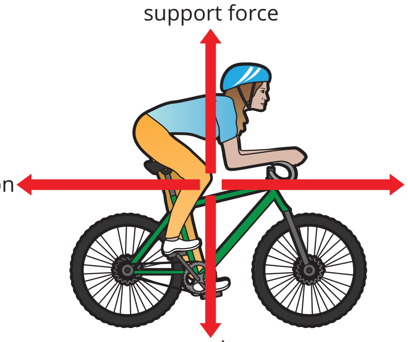


FIGURE 1.10.3 The forces acting on the bike and its rider are equal in size and opposite in direction.

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 size of the arrows is the same. The down and up pair (gravity and support force) are also balanced.

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

KEY TERM

net force the combination of multiple forces acting on a single object; also called resultant 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.

SkillBuilder

Calculating net force on an object

Important information

In most situations, more than one force is acting on an object. The net force is the combination of these different forces. It is the overall force that the object experiences.

If the net force is zero, the forces are balanced.

If the net force is not zero, the forces acting on the object are unbalanced.

Like all forces, the net force on an object will have a direction; for example, up, down, to the right or to the left.

How to calculate net force

Identify all the forces acting on the object.

1 Sketch a diagram showing the strength and direction of these forces.
2 Decide how you will describe the direction of the forces (for example, up / down / north / south / forwards / backwards / to the right / to the left).
3 If forces are acting in the same direction, add the values of the forces together to calculate the total force in that direction.
4 If forces act in opposite directions, subtract the smaller force from the larger one to calculate the net force.
5 State the value and the direction of the net force.

For example, Reuben was asked to calculate the net force acting on a ball that had been pushed under the surface of a swimming pool.

The buoyancy force was 30 N, and the force due to gravity was 4 N as shown in Figure 1.10.4.

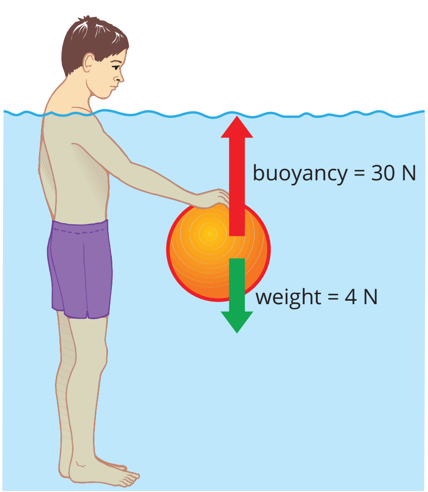


FIGURE 1.10.4 The upwards buoyancy force and the downwards weight force act on the ball.

The forces act up and down in opposite directions, so he calculated the net force by taking the smaller force away from the larger one.

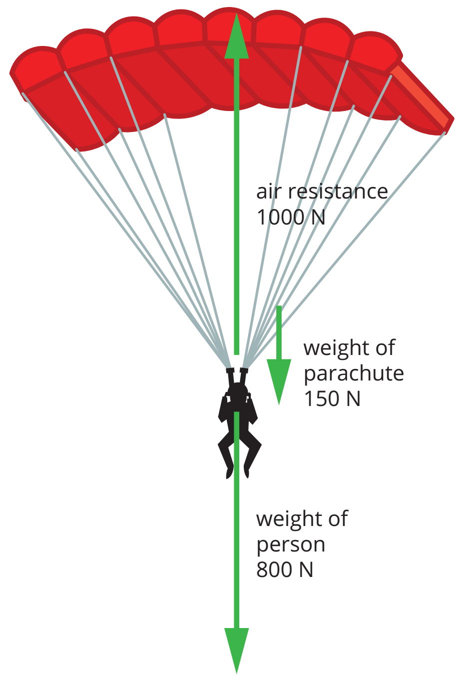
net force = 30 – 4 = 26 N (upwards)

Worked example

Calculating net force on an object

Consider a parachutist and their parachute falling through the air. The weight of the parachute is 150 N, and the weight of the parachutist is 800 N. The total air resistance acting on the parachute and the parachutist is 1000 N.

Calculate the net force acting on them.

Thinking	Working
Identify all the forces acting on the object.	weight of parachute (150 N) weight of the parachutist (800 N) total air resistance (1000 N)
Draw a force diagram showing the forces acting on the object.	
Add the values of the downward forces together to calculate the total force in that direction.	Total downwards force = 800 + 150 = 950 N
Determine the total force acting upwards.	Total upwards force = 1000 N
Determine the net force by calculating the difference between the total upwards and total downwards forces. Note the direction of the largest total force.	Net force = 1000 – 950 = 50 N upwards

Try yourself

A cyclist produces 20 N of force to move a bicycle forward. The friction acting against the bike is 10 N, and the air resistance caused by a strong headwind is 15 N.

Calculate the net force on the bike and cyclist.

The effect of the 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 stationary. For example, the student in Figure 1.10.5 does not move up or down because there is a zero net force acting in the vertical direction.

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 the cyclist and bike (Figure 1.10.6) is balanced with friction, there is a net force of zero. They will move down the hill at constant velocity.

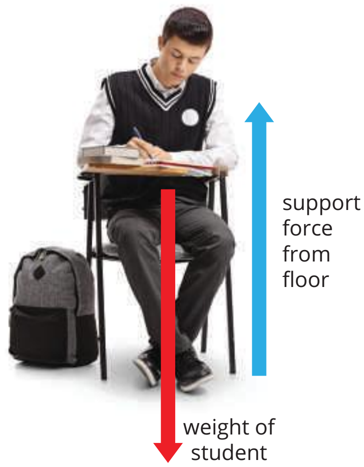


FIGURE 1.10.5 Equal and opposite forces act on a student sitting still in a chair.

FIGURE 1.10.6 Although the cyclist may be moving very fast, unbalanced forces are required to make them change velocity (accelerate).

Unbalanced forces

When the forces on an object are not balanced, there will be a net force acting on the object. The direction of the net force 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. The object has accelerated from zero velocity.

For example, the net force on the book (Figure 1.10.7) is 4 N to the right, so the book will start to move to the right.

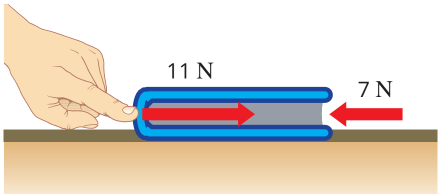


FIGURE 1.10.7 The book will move in the same direction as the larger force.

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 1.10.8, 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.

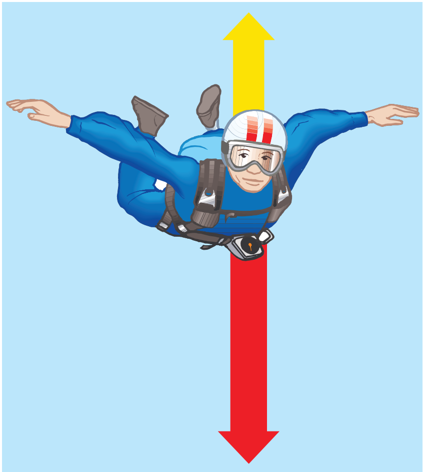


FIGURE 1.10.8 The skydiver will accelerate until they reach terminal velocity.

Objects moving in the opposite direction to the net force

If an object experiences a push or pull in the opposite direction to which it is travelling, it will decelerate. This means that the object will slow down and possibly stop.

Scifile

Sink or swim

An object in the water has two main forces acting on it: the force due to gravity, which acts downwards, and the buoyancy force, which acts upwards. When the forces are balanced, the object will stay floating. If the forces are unbalanced, the object will sink or rise. This is an important concern for ships, where the maximum load of the ship needs to be calculated carefully. If a ship is accidentally overloaded, it may be at risk of sinking.

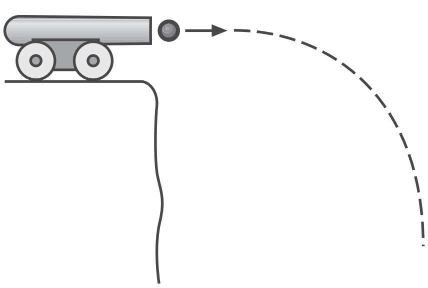


FIGURE 1.10.10 The force of gravity pulling the cannonball down makes it move in a curve.

In Figure 1.10.9, the net force on the car is in the opposite direction to its movement. It will decelerate and possibly stop.

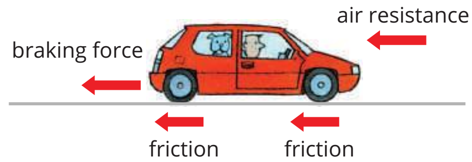


FIGURE 1.10.9 All forces acting on the car are opposite the direction of motion.

Net force acting from the side of a moving object

A moving object experiencing a sideways push or pull, will change direction. This is because the net force causes the object to accelerate in a different direction.

Although it is fired horizontally, the force due to gravity acting on the cannonball causes its motion to be directed towards Earth. The cannonball has changed direction and is accelerating downwards (Figure 1.10.10).

SC 2 CHECK YOUR UNDERSTANDING

Explain how to determine the direction of the net force when multiple forces act on an object.

SC 3 I can explain the concept of terminal velocity when forces are balanced

Some forces that act against the movement of an object, such as air resistance, become stronger as the object travels faster.

If an object is accelerating due to the action of gravity, the object will move faster and faster, and the force acting against the movement will get stronger and stronger.

Eventually, the opposing force (in other words, the air resistance) will become the same strength as the force causing the motion (gravity). At this point, the forces are balanced. The net force is zero.

This can be seen in the graph in Figure 1.10.11.

The object 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. The speed of the object at this point is called terminal velocity.

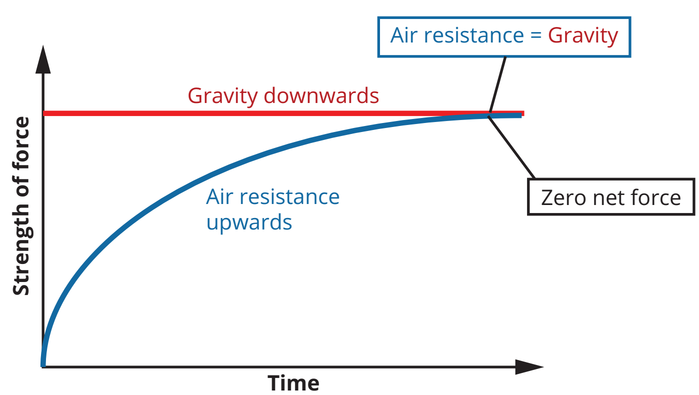


FIGURE 1.10.11 Strength of force over time for an object falling under the effects of gravity

Terminal velocity of a skydiver

A skydiver will experience terminal velocity as shown in Figure 1.10.12.

The smaller the surface area of the skydiver, the faster the terminal velocity.

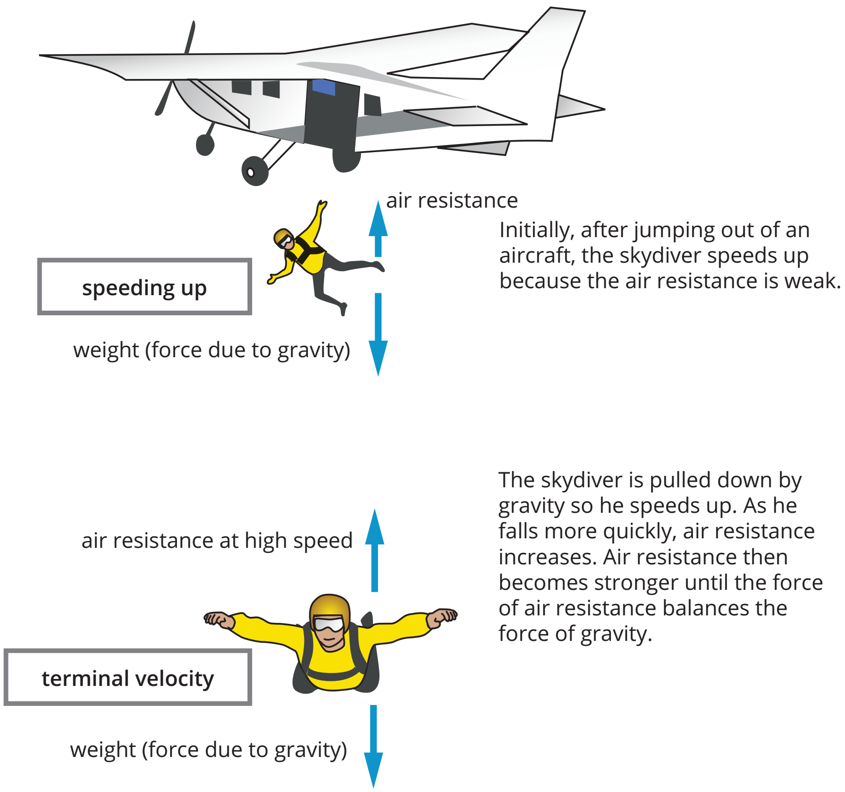


FIGURE 1.10.12 The skydiver reaches terminal velocity when the air resistance is equal in magnitude and opposite in direction to the force due to gravity.

SC 3 CHECK YOUR UNDERSTANDING

Define terminal velocity.

Lesson review

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

1 Draw a vector diagram to represent the forces acting on a stationary box on a flat surface.

2 Compare vector 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 two different objects, a feather and a stone, to understand terminal velocity.

- **a** Describe the forces acting on both objects as they fall.
- **b** Explain why the feather reaches terminal velocity more quickly than the stone.

1.11 Aircraft design

Learning intention

To be able to explain how aeronautical engineers' understanding of forces has led to changes in aircraft design

Success criteria

SC 1: I can describe the nature of forces acting in flight that have influenced aircraft design.

SC 2: I can create a two-dimensional or three-dimensional model of an aircraft to demonstrate the four forces of flight (lift, drag, gravity and thrust).

SC 3: I can explain the changes in aircraft design over time, including environmental and economic considerations.

Introduction

An aircraft in flight is acted upon by four forces. These four forces are:

- lift – the upward-acting force
- gravitational force (weight) – the downward-acting force
- thrust – the forward-acting force
- drag – the backward-acting force (also known as air resistance).

Aeronautical engineers have developed aircraft design over time due to their increased understanding of the nature of these forces acting in flight.

In this inquiry activity, you will explore the four forces of flight and investigate how aircraft design, such as the aircraft featured in Figure 1.11.1, has changed over time.

FIGURE 1.11.1 Formation flying requires pilots to have a high level of control over the forces acting on their aircraft.

Background

An aircraft in flight is acted on by four forces – **lift force**, **gravitational force** (also called 'weight'), **thrust force** and drag force, as demonstrated in Figure 1.11.2. Understanding more about these forces has enabled aeronautical engineers to make changes and improvements to aircraft design.

FIGURE 1.11.2 The four forces act in different directions on the aircraft to maintain flight.

KEY TERMS

lift force an upward-acting force produced by an object moving through a gas or liquid

gravitational force the force on an object due to gravity; can be described as the 'weight' of an object

thrust force a force that causes an object to move forward

When considering all the forces acting on an aircraft, it can be helpful to calculate the net force. You can do this by looking at the magnitude and directions of all the forces combined.

For example, consider the van in Figure 1.11.3 which is travelling along a road. The van has a driving force of 30 N forwards and resistive forces of 10 N acting backwards.

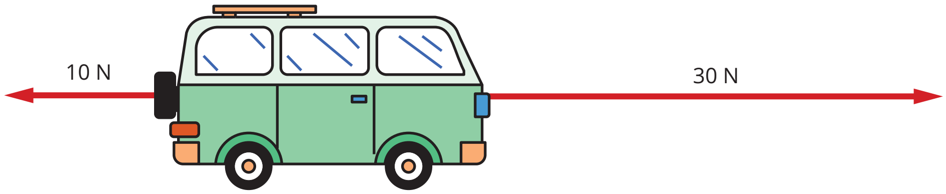


FIGURE 1.11.3 There are unbalanced forces acting on the van.

As the van experiences 30 N in the forwards direction, but 10 N in the backwards direction, the net force will be 30 – 10 = 20 N forwards.

As aircraft have four main forces acting on them, being able to calculate net forces is important to determine the motion of the plane. The vertical motion of the aircraft is determined by the lift and weight. The horizontal speed of the aircraft, due to acceleration or deceleration, is determined by the drag and thrust acting on it.

Aim

To investigate how aeronautical engineers' understanding of forces has led to changes in aircraft design

Plan

Focusing on more recent developments over the past 20 years, investigate the changes in aircraft design over time. Some of the developments you could consider exploring are efficiency of engines, aerodynamic and wing design changes and the changing materials used to build aircraft.

Consider how these changes have had environmental or economic benefits. For example, how have engines become more efficient? How has this efficiency benefited the environment and the cost of travel?

Select one aspect of aircraft design to focus your research on.

Develop three investigation questions to guide your research.

GO TO
Toolkit section 1.1, Investigable questions

Design

When conducting your research, you need to make sure you are using reliable websites. This is the best way to ensure your information is accurate and relevant for modern aircraft design.

Look into some reliable websites you can use for your investigation and record them to be checked by your teacher before conducting your research.

GO TO
Toolkit sections 4.3, Selecting and using secondary data and 4.2, Referencing secondary data

Conduct

Conduct your internet research and record your findings.

Use your research to create a two-dimensional or three-dimensional model of an aircraft that demonstrates how the feature you researched contributes towards improvements in aircraft design.

GO TO
Toolkit section 5.1, Scientific writing

Improve

Describe how you can improve your investigation by considering the following.

- What worked well?
- What needed improvement?
- How could you modify your research and findings about aircraft design to make it better?

Evaluate

1 Write a summary of your findings about how aeronautical engineers' understanding of forces have led to changes in aircraft design.

2 Describe the skills used during your investigation and identify whether these skills helped you understand the forces used in aircraft design.

1.12 Influence of cultural knowledge on developments in aerodynamics

Lesson overview

Cultural perspectives and **worldviews** play an important role in the development of scientific knowledge. For example, the rich cultural heritage of First Nations Australians significantly influenced the early development of aerodynamics.

Among the many iconic tools in First Nations Australian culture, the boomerang stands out. Traditionally crafted from wood, it was designed for both hunting purposes and as a tool. However, its impact extends beyond these practical applications. In fact, it may surprise you to learn that the boomerang played an important role in paving the way for the invention of one of the first helicopters.

In this lesson, you will explore the fascinating story of David Unaipon (Figure 1.12.1), a Ngarrindjeri man from the Coorong region of South Australia, to learn about how his clever understanding of forces and motion made an important contribution to the science of flight.

Learning intention

To understand how cultural knowledge and understanding of the aerodynamic properties of boomerangs supported the conception of a vertical lift machine

Success criteria

SC 1: I can describe how cultural knowledge has influenced the development of scientific knowledge of aerodynamics.

SC 2: I can explain how David Unaipon, a Ngarrindjeri man from the Coorong region of South Australia, helped to conceptualise a 'vertical lift flying machine' in 1914.

KEY TERM

worldview how someone understands and interprets the world, including what they believe is true and what they think is important

SC 1 I can describe how cultural knowledge has influenced the development of scientific knowledge of aerodynamics

Aerodynamics is the study of how objects move through the air, whether it is a rocket launching or a kite soaring against the wind. It explains the dynamics of objects in flight, including gravity, lift, thrust and drag. Lift, for example, is the force that allows an object to move upwards, often generated by the wings, to counteract gravity. Thrust is the force that allows the object to move through the air and is opposed by the mechanical force of drag.

First Nations Australians have a strong understanding of objects in flight stretching back generations (Figure 1.12.2). This knowledge supported the development of aerodynamic principles in Western science that continues today.

FIGURE 1.12.1 This is an image of David Unaipon, a Ngarrindjeri man from the Coorong region of South Australia.

FIGURE 1.12.2 Willie Gudubi carves a traditional beefwood boomerang in Ngukurr, south-east Arnhem Land, Northern Territory.

This lesson introduces David Unaipon, the Ngarrindjeri man who considered the creation of a 'vertical lift flying machine' in 1914, as well as the invention, cultural use and aerodynamic properties of his key inspiration: the boomerang.

Invention and cultural use of the boomerang

FIGURE 1.12.3 These boomerangs, made by the Kaurna people of the Adelaide plains, are on display at the South Australian Museum in Adelaide.

The boomerang (Figure 1.12.3) is a marvel of both cultural significance and scientific complexity. Although its origin remains uncertain, it is widely believed to have emerged on the Australian continent. First Nations Australians harnessed the boomerang's unique properties to create two main types: the returning and non-returning varieties.

These versatile tools were developed primarily for hunting, serving as weapons in the pursuit of birds, kangaroos, emus, and other marsupials. One clever hunting technique involves capturing birds by creating nets suspended between trees, then imitating a hovering hawk with skilfully thrown boomerangs. However, the boomerang's uses extend far beyond hunting, as they are often beautifully decorated and used in ceremonies, storytelling and musical expressions.

Aerodynamics of the boomerang

The aerodynamic properties of a boomerang include its convex (curved outward) top surface, distinctive curved, thin body, and wide surface area. Each of these features contributes to the boomerang's ability to fly effectively.

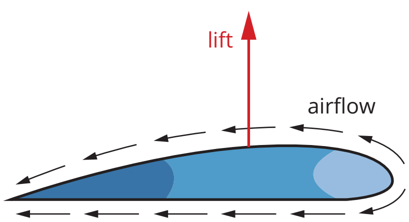


FIGURE 1.12.4 The airflow over the boomerang as it flies creates a lift affect due to its convex shape.

- **Convex top surface**: The convex shape of the boomerang's top surface generates lift as air flows over it (Figure 1.12.4). Lift counteracts the force of gravity, allowing the boomerang to stay airborne for longer.
- **Distinctive curve:** The distinctive curve of a boomerang contributes to its stability in flight. Coupled with the spin created during the throw, its shape helps to maintain a steady flight path.
- **Thin body:** The boomerang's thin body reduces drag, allowing the boomerang to move more efficiently through the air. Lower drag enhances the boomerang's ability to travel longer distances.
- **Wide surface area:** The boomerang's wide surface area provides a large area for air to interact with, contributing to lift and stability (Figure 1.12.5). It also aids in resisting the downward pull of gravity.

FIGURE 1.12.5 Aerodynamics of a boomerang in mid-air

When a boomerang is thrown correctly, these features work with the following aerodynamic forces to keep it in the air.

- **Thrust and lift:** The initial thrust from the throw, combined with the lift generated by its convex surface, propels the boomerang forwards and upwards.
- **Gravity:** The boomerang's weight, or force due to gravity, acts downward, but the lift force opposes it, allowing the boomerang to stay in the air.
- **Spin stabilisation:** The spin created during the throw stabilises the flight path, preventing unpredictable movements.
- **Drag:** The thin body minimises drag, enabling the boomerang to maintain speed and remain in the air.

As the boomerang completes its flight and returns, it continues to experience lift, drag and the effects of gravity. The balance of these forces, along with the boomerang's unique design, causes it to circle back towards the thrower. Timing the catch is important. The downward force of gravity and the spin of the throw work together to guide the boomerang back into the thrower's hands.

SC 1 CHECK YOUR UNDERSTANDING

Explain how the shape of a boomerang is designed to oppose the force of gravity as it travels through the air.

SC 2 I can explain how David Unaipon, a Ngarrindjeri man from the Coorong region of South Australia, helped to conceptualise a 'vertical lift flying machine' in 1914

David Unaipon—the aviation inventor

David Ngunaitponi (28 September 1872 – 7 February 1967), widely known as David Unaipon, was a Ngarrindjeri man from Point McLeay Mission, a place now recognised as Raukkan in the Coorong region of South Australia. Unaipon is remembered as an inventor, writer and speaker and is commemorated on the Australian 50 dollar note.

Interestingly, it was Unaipon's invention of the mechanical shears that encouraged his groundbreaking work in aviation: the development of the vertical lift flying machine.

The early life and cultural background of David Unaipon

The waterways of the lower Murray River, Lower Lakes and Coorong region (Figure 1.12.6) were once among the most densely populated areas of Australia and home to thousands of Ngarrindjeri people. Their connection to this region was life giving and rewarding with many resources at their disposal, including food, medicine, shelter, warmth and clean waters. After European settlers arrived in the region, Ngarrindjeri were employed in seasonal work such as agricultural labour, fishing and other industries that emerged. However, they still used this land for shelter and resources. To this day, First Nations Australians keep culture alive by continuing to visit special places such as this and sharing stories.

FIGURE 1.12.6 Coorong region of South Australia

David Unaipon was born on 28 September, 1872. Growing up, he faced educational restrictions common for many First Nations Australians at the time. Despite limited formal schooling, however, Unaipon showed a keen interest in self-directed learning, and demonstrated a talent for science, literature and philosophy.

Unaipon went on to work in other roles such as a servant, labourer and seasonal worker, experiencing financial challenges while maintaining a commitment to increasing his knowledge. His early years were filled with obstacles, but his intellect and passion for learning eventually saw him recognised as an important figure in the fields of science and literature. Unaipon would later become famous for his innovative thinking and inventions.

The mechanical shears

The 50 dollar note features an image of David Unaipon with Point McLeay Mission in the background. It also depicts one of Unaipon's most notable inventions, the mechanical shears, which showcased his ability to convert curved motion into the straight-line movement seen in modern mechanical shears. His ability to transform motion in this way assisted his later invention of the vertical lift machine.

Unaipon's unique insights into mechanical processes may have been inspired by cultural practices that influenced his inventive thinking. Indeed, he is quoted on the 50 dollar note (Figure 1.12.7) as saying 'as a full-blooded member of my race I think I may claim to be the first—but I hope, not the last—to produce an enduring record of our customs, beliefs and imaginings'.

FIGURE 1.12.7 David Unaipon pictured on Australia's 50 dollar note with a sketch of the mechanical shears

The vertical lift flying machine

David Unaipon proposed that the aerodynamic properties of the boomerang could be adapted for vertical flight in 1914; this was 22 years before the first operational helicopter was invented. Boomerangs fly roughly parallel to the ground and as long as they maintain sufficient speed and rotation, they can overcome the force of gravity. Using this principle as his inspiration, Unaipon developed plans for a flying machine that used spinning blades to rise straight up from the ground.

Of his invention, he said 'When I solved the flight of the boomerang … it seemed to me that I could do away with the preliminary run of the aeroplane, and make the machine rise direct from the ground. I know that certain laws on which I work have not been tried before, but I am quite sure I shall be successful. I am aware of the opposing forces; but I know what to do to overcome them.'

Unaipon was not able to make his vertical lift flying machine a reality during his lifetime, but in 2023, students at the University of New South Wales Sydney built a boomerang-powered flying machine based on Unaipon's designs from over 100 years ago. Using miniature 3D-printed boomerangs to form rotor blades on a drone, the students were able to achieve vertical flight and confirm that Unaipon's theory was correct.

SC 2 CHECK YOUR UNDERSTANDING

Explain the significance of David Unaipon's work on the vertical lift flying machine.

Scifile

Australian innovations in vertical lift machines

Australia has a rich history of innovation in vertical lift machines, inspired by the aerodynamic properties of the boomerang. Engineers and researchers have developed various technologies for vertical take-off and landing (VTOL) aircraft. These machines can hover, take off and land vertically, making them ideal for urban air mobility, and search and rescue operations.

One example of continuing aerodynamic innovation in Australia is the recent development of 'Project Vertiia', a renewable hydrogen-powered VTOL (eVTOL), which is being researched in conjunction with CSIRO.

VTOL aircraft, like Vertiia, make use of rotors to provide vertical lift.

Lesson review

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

1 Identify what innovation was inspired by David Unaipon's cultural background.

2 Describe which feature of boomerangs reduces drag, allowing it to travel faster.

3 Compare David Unaipon's vertical lift flying machine concept with modern helicopters.

4 Consider how cultural knowledge of boomerangs influenced the development of aerodynamic principles.

   a Describe the cultural significance of boomerangs in First Nations Australian culture.

   b Explain the aerodynamic principles that allow a boomerang to return to the thrower.

   c Discuss how these principles contributed to the scientific understanding of aerodynamics.

1 Forces and motion

Topic summary

The key concepts included in this topic are:

- Force is measured in newtons (N) and forces can be classified as contact or non-contact forces. Forces can be represented on force diagrams using the size 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 speed. If the forces acting on an object are unbalanced, the object will speed up, slow down or change direction.
- Friction is caused by microscopic bumps in the surfaces of touching objects, which act to oppose the direction of motion.
- Levers can be categorised depending on where the effort, fulcrum and load is located. Increasing the distance between the effort and the fulcrum of a lever can magnify the effect of the applied force.
- Aircraft are able to fly because they make use of lift and thrust to overcome drag and the force due to gravity.
- First Nations Australians demonstrated 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 frictional force.

4 List the four forces that act on an aircraft in flight.

5 Define the term ‘trend’ when analysing experimental data.

Understand

6 Explain how the length of a force arrow relates to the magnitude of the force.

7 State the difference between contact and non-contact forces and provide examples of each.

8 Describe how lift and thrust affect an aircraft’s flight.

9 Explain the importance of controlling variables in an investigation. Refer to the reliability of the collected data in your response.

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 right and a frictional force of 5 N 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 Propose a hypothesis about the relationship between mass and friction.

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** Compare the presence of frictional forces when walking on grass to walking on a smooth surface such as ice.
- **c** 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.

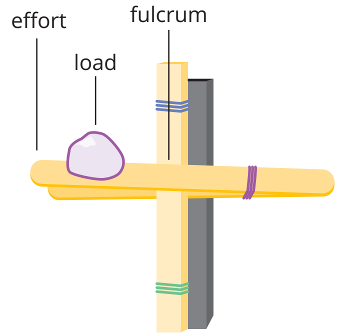
- **a** Identify who David Unaipon was.
- **b** Explain how cultural knowledge of boomerang aerodynamics influenced David Unaipon's work.
- **c** Describe how the aerodynamic properties of boomerangs were used to propose a vertical lift machine.

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 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 ice-cream sticks, elastic bands and cotton balls.

Make the catapult shown in the image below. Test your device before continuing and make any final adjustments to your elastic bands.



- Arrange your device so the fulcrum is in the centre of your ice-cream 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 pattern 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 particular areas that you are confident in, and others where you are not so sure.

1 Glossary

acceleration increase in speed (verb: accelerate)

air resistance friction that acts on an object moving through the air

balanced forces forces acting on a single object where the force in one direction is equal to the force applied in the opposite direction

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

constant velocity the movement of an object at the same speed and in the same direction

contact force a force that acts between two objects that touch each other

deceleration decrease in speed (verb: decelerate)

drag force a force created by an object moving through a gas or liquid

effort a force applied to a lever to overcome the load

estimate an approximate judgement of the value or amount of time

first-class lever a lever with effort and loads at each end, and fulcrum in the centre

force any interaction that will change the motion of an object when unopposed; 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 a force that acts against an object's motion

fulcrum a 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 the force of attraction between any two objects

lever a simple machine consisting of a rigid rod that pivots about a point

lift force an upward acting force produced by an object moving through a gas or liquid

load a force, often a weight, on a lever or material

magnitude a measure of the size or strength of something

mnemonic a pattern of letters which helps to remember something

net force the combination of multiple forces acting on a single object; also called resultant force

newton (N) the unit used to measure force

newton meter a device used to measure the strength of a force; often called a spring balance

non-contact force a force that acts on an object from a distance

point of reference something that is used for comparison

preliminary trial a trial of an experiment used to test a method

second-class lever a 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 a lever with the fulcrum at one end, the effort in the centre, and the load at the other end

thrust force a force that causes an object to move forward

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

vector a quantity that has magnitude and direction

vector diagram a graphic that uses arrows to represent the effect of one or more vectors

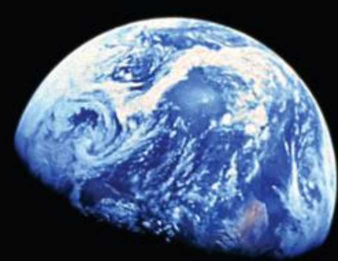
velocity the speed and direction of an object

worldview how someone understands and interprets the world, including what they believe is true and what they think is important

TOPIC
2
Systems in space: The Earth, Sun and Moon

There is so much to see when looking up at the night sky; the Moon and its craters, the stars and planets, and even meteors and comets. While all these objects in space are very far away, they can still have an impact here on Earth.

In this topic you will learn about the Earth, Sun and Moon systems, and how their interactions are experienced on Earth, such as the changing seasons, eclipses and tides.

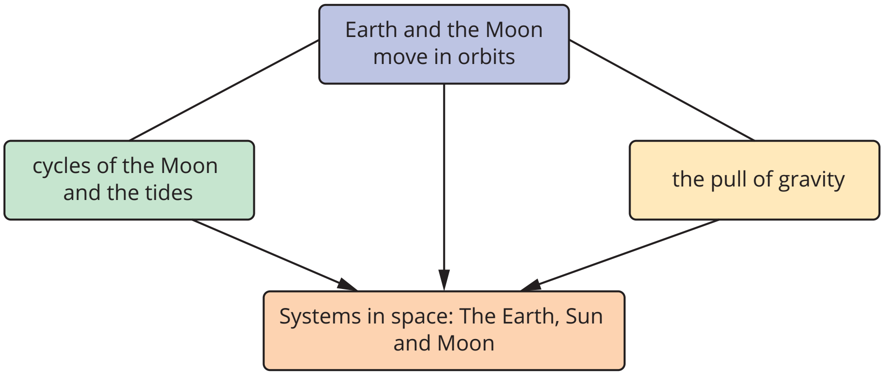


Learning intentions

- ☐ To understand the structure of the Earth, Sun and Moon system **59**
- ☐ To understand how the position and motion of Earth causes seasons **64**
- ☐ To be able to use equipment to model the effect of the angle of the Sun on surface temperatures **73**
- ☐ To understand seasonal calendars used by First Nations Australians **76**
- ☐ To understand how the position of Earth and the Moon causes tides **80**
- ☐ To understand how information about tides is used in society **85**
- ☐ To understand the phases of the Moon **94**
- ☐ To be able to create and use a model to describe the phases of the Moon **99**
- ☐ To understand the cause of a lunar eclipse **101**
- ☐ To be able to explore the influence of cultural perspectives on scientific knowledge about lunar eclipses **108**
- ☐ To understand the cause of a solar eclipse **110**
- ☐ To be able to explain how a range of factors have influenced the exploration of the Moon **115**

2 Systems in space: The Earth, Sun and Moon

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 The Earth, Sun and Moon system

Lesson overview

Earth, the Sun and the Moon are connected in space by the pull of gravity. They all travel through space, and their movements create observable effects from your vantage point on Earth.

Throughout the year, days become longer or shorter during the seasons and you can see changes in the phases of the Moon and night sky. Earth, the Sun and the Moon interact in a predictable way. This is known through observations and knowledge of gravity and the relative sizes and distances between these objects. In this lesson, you will learn about the Earth, Sun and Moon system and how these objects interact in space.

Learning intention

To understand the structure of the Earth, Sun and Moon system

Success criteria

SC 1: I can describe the relative positions and sizes of Earth, the Sun and the Moon.

SC 2: I can describe the relative motion of Earth, the Sun and the Moon.

SC 3: I can explain the role of gravity in the movement of Earth, the Sun and the Moon.

SC 1 I can describe the relative positions and sizes of Earth, the Sun and the Moon

The **Sun** is the centre of the **solar system**. The solar system includes all objects that travel around the Sun: the eight **planets**; smaller bodies such as dwarf planets, meteors, comets and asteroids; and natural satellites such as the **Moon**. The force of **gravity** is responsible for the attraction between objects and keeps these objects, including Earth, travelling around the Sun.

Earth, the Sun and the Moon in space

Thinking about distance and size in **space** can be very difficult because everything is very far apart and some objects in the solar system are so much larger than Earth. It helps to consider how other objects in space relate to Earth.

How big is Earth?

The diameter of Earth at the equator is 12 756 km.

FIGURE 2.1.1 Earth's mass is approximately 83 times larger than the Moon's mass.

KEY TERMS

Sun a massive, luminous ball of hot gas located at the centre of the solar system, emitting light, heat and energy that reach Earth and other planets

solar system the Sun and all the planets, satellites, asteroids, comets and other bodies revolving around it

planet a roughly spherical ball of rock or gas that orbits (moves around) the Sun; planets do not generate their own light

Moon a natural satellite that orbits Earth

gravity the force of attraction between any two objects

space the immense and limitless area beyond Earth's atmosphere, containing stars, planets, galaxies and other cosmic matter

mass the amount of matter in a substance or an object; measured in grams (g), kilograms (kg) or tonnes (t)

Scifile

Scientific notation

Scientific notation is a method used to express very large or very small numbers in a more compact and manageable form. It is especially useful in fields like science and engineering where these types of numbers are common.

For example, the number 1 000 000 can be written as 1×10^6.

The mass of Earth in scientific notation is 5.972×10^{24} kg.

10^{24} written in expanded form is a 1 followed by 24 zeros

$= 5.972 \times 1\,000\,000\,000\,000\,000\,000\,000\,000$

$= 5\,972\,000\,000\,000\,000\,000\,000\,000$

This number is 5.972 septillion!

Now compare Earth's mass with those of the Moon and the Sun:

The mass of the Moon is 7.342×10^{22} kg.

The mass of the Sun is 1.988×10^{30} kg.

Scifile

Distance in space

The average distance from Earth to the Moon is about 384 400 km. That is like travelling around Earth's equator almost 10 times! Despite this distance, the Moon's gravity still affects Earth. The Moon looks small in the sky because of how far away it is. It is actually slightly smaller in diameter than Australia, about a third of Earth's diameter.

How big is the Moon?

The Moon is smaller than Earth (Figure 2.1.1) and much smaller than the Sun. It has a diameter of 3480 km, which is less than a third of Earth's diameter. The Moon's **mass** is only about 1.2% of Earth's mass. On average, the distance between Earth and the Moon is 384 400 km.

How big is the Sun?

The Sun is very large, much bigger than Earth, and represents most of the mass in the entire solar system. The image in Figure 2.1.2 gives you an idea about the size of the Sun compared to Earth and the other planets. The Sun's diameter is about 1.392 million kilometres, which is at least 109 times bigger than the diameter of Earth, so you could fit 109 Earths across the Sun. The mass of the Sun is about 333 000 times the mass of Earth.

The distance between the Sun and Earth is approximately 150 million kilometres.

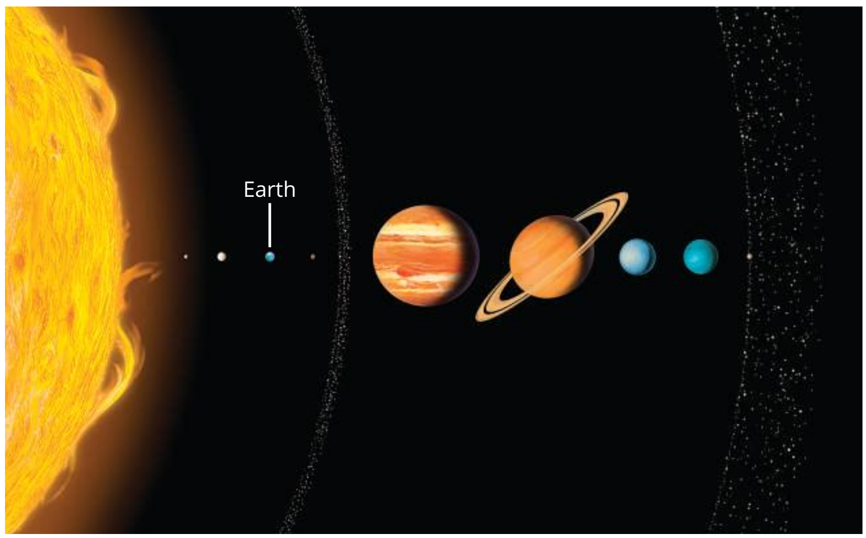


FIGURE 2.1.2 The Sun's mass is about 333 000 times the mass of Earth.

The Earth, Sun and Moon system

In space, the Moon and Earth are relatively close together compared to their distance to the Sun. The Sun and the Moon also differ greatly in size, as the Sun is about 400 times larger than the Moon. The Sun also happens to be almost 400 times by away from Earth than the Moon, and this causes the Sun and the Moon to look the same size from your perspective on Earth.

SC 1 CHECK YOUR UNDERSTANDING

Rank Earth, the Sun and the Moon by size (from smallest to largest) and the Sun and the Moon by distance from Earth (from closest to most distant).

SC 2 I can describe the relative motion of Earth, the Sun and the Moon

Everything in the solar system is always moving. The forces between the Sun, Earth and the Moon cause movements that can be observed from Earth.

Orbits

The force of gravity can cause objects in space to revolve around others in an **orbit**. An orbit is a curved path like a circle, an ellipse or a symmetrical oval. Earth travels in an almost circular orbit around the Sun.

It takes Earth 365.25 days, or one year, to orbit the Sun. A normal calendar year has 365 days—which does not quite match Earth's orbit. So, to keep the calendar year aligned with the time it takes Earth to revolve around the Sun, an extra day is added to the calendar every four years, which creates leap years. Leap years have 366 days.

While Earth is travelling around the Sun, the Moon orbits around Earth. It takes the Moon 27.3 days to orbit Earth. Figure 2.1.3 shows both these motions and how long each of them takes.

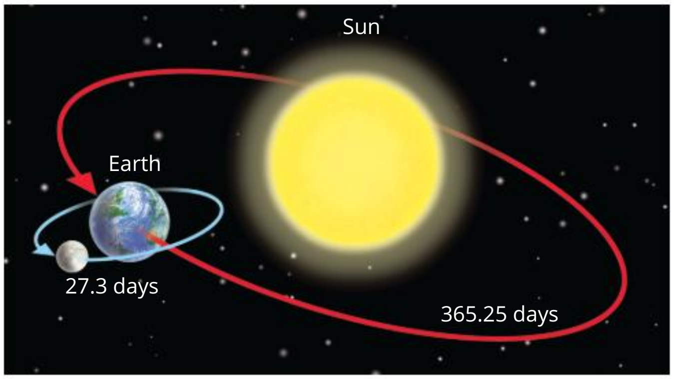


FIGURE 2.1.3 The orbit of Earth around the Sun defines one year; in this time, the Moon completes many orbits of Earth.

Rotation

While Earth and the Moon are travelling in orbits in space, the Sun, Earth and the Moon are also constantly spinning. This spinning motion is called **rotation** and occurs around an axis. An axis is an invisible line that objects rotate around. You can imagine **Earth's axis** as a line through the middle of Earth from the North Pole to the South Pole (Figure 2.1.4).

Day and night

Earth's rotation on its axis results in a cycle of daylight and darkness, or day and night, every 24 hours. As Earth rotates, the side of Earth facing the Sun receives light and experiences day. The other side of Earth, which faces away from the Sun, is in darkness and experiences night. As Earth rotates, it seems as though the Sun is moving across the sky, but it is really Earth that is moving. It is said that the Sun rises and sets at the beginning and end of each day but it is Earth's rotation that makes it look like the Sun is appearing or disappearing over the horizon (Figure 2.1.5).

SC 2 CHECK YOUR UNDERSTANDING

Identify the object that Earth orbits around.

KEY TERMS

orbit the curved path of a planet around a star, or of a moon or artificial satellite around a planet; orbits can be circular or elliptical

rotation the spinning motion of an object around a central line, called an axis of rotation

Earth's axis the line connecting the North Pole with the South Pole; Earth rotates around this axis

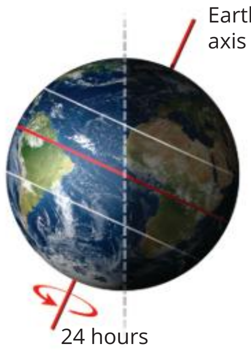


FIGURE 2.1.4 It takes Earth 24 hours, or one day and night, to complete a full rotation on its axis; the Sun and the Moon take about 27 days to complete a full rotation.

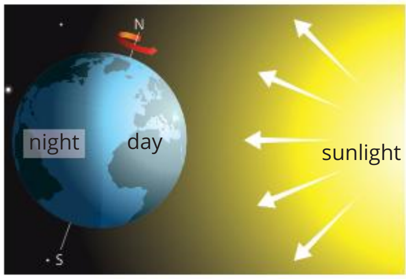


FIGURE 2.1.5 When you are on the part of Earth where you see light from the Sun, you call it daytime. When you are in the shadow of Earth, you call it night. So, the experience of day or night depends on your position on Earth.

SC 3 I can explain the role of gravity in the movement of Earth, the Sun and the Moon

Gravity is the force that attracts objects to each other in space. Any object with mass will attract any other object with mass. The Sun, the Moon and Earth all exert gravitational forces, pulling objects toward their centre. Objects with more mass have a stronger gravitational pull, but the force of gravity also decreases with distance. So, the farther you travel away from an object, the weaker the force of gravity you will experience.

Gravity and orbits

Earth, and all other objects in the solar system, have a very strong gravitational attraction to the Sun due to its immense mass. Even though the distance between the Sun and Earth is very large, the Sun's gravitational pull is strong enough to keep Earth in its orbit around the Sun.

The Moon and Earth are relatively close to each other in space. Earth has much more mass than the Moon. Earth's gravity keeps the Moon in its orbit around Earth. The diagram in Figure 2.1.6 is not to scale but will help you to visualise the relationship between the Moon, Earth and the Sun.

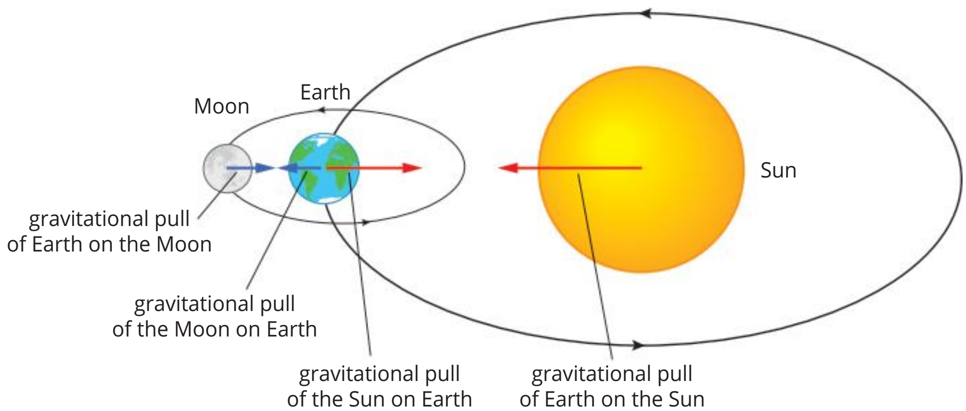


FIGURE 2.1.6 force of gravity acting on Earth due to the Sun keeps Earth in its orbit around the Sun. The gravitational forces between Earth and the Moon are also shown and it is the pull of Earth on the Moon that keeps the Moon in its orbit around Earth.

Keeping steady

Stable orbits happen when the force of gravity is combined with an object moving at the right speed through space. For example, the Moon is travelling at a speed that would ordinarily cause it to travel through space in a straight line, but Earth's force of gravity pulls on the Moon, keeping it in an orbit.

The Moon's speed also stops the Moon from being pulled to the centre of Earth and crashing down on us. The combination of the Moon's speed and Earth's gravity keeps the orbit steady (Figure 2.1.7).

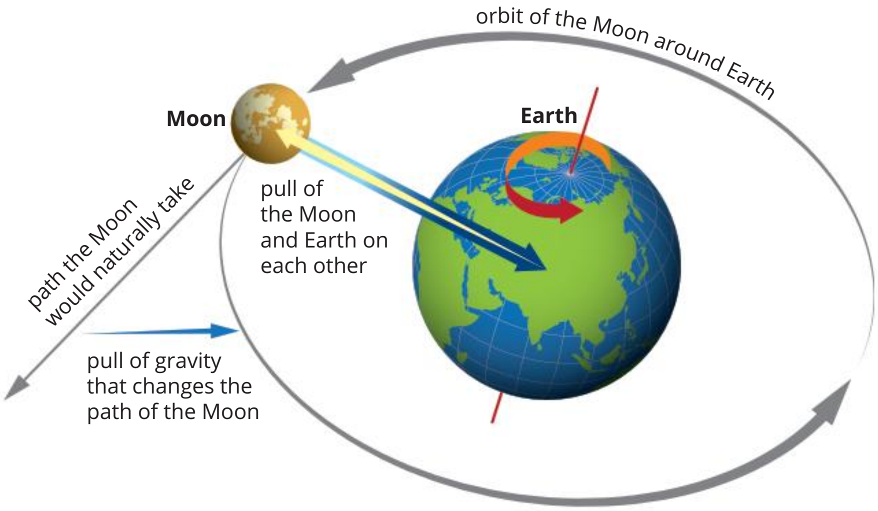


FIGURE 2.1.7 The pull of gravity of the Moon and Earth on each other keeps the Moon in orbit around Earth.

Satellites

The Moon is Earth's natural satellite. A **satellite** is a body in orbit around another body. Many artificial satellites are created to orbit Earth. Something that scientists must consider when they launch satellites into orbit is their speed. As shown in Figure 2.1.8, if a satellite is moving too fast (Satellite B), Earth's gravity won't be strong enough to keep the satellite in orbit and it will move into space. If the satellite is moving too slowly (Satellite C), Earth's gravity will pull the satellite back down to Earth. When the satellite is moving at just the right speed (Satellite A), it will stay in a fixed orbit around Earth.

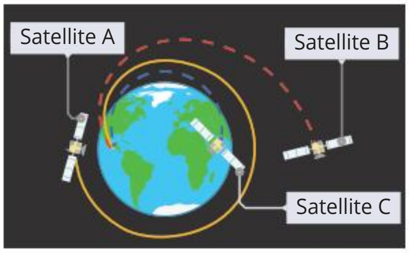


FIGURE 2.1.8 The speed of a satellite must be correct for it to stay in an orbit at a certain distance from Earth.

SC 3 CHECK YOUR UNDERSTANDING

Explain how gravity keeps the Moon in orbit around Earth.

Lesson review

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

1 Compare the sizes of Earth, the Sun and the Moon. Which one is the largest and which one is the smallest?

2 Illustrate the approximate sizes and arrangement of Earth, the Sun and the Moon using common objects (such as a basketball, a tennis ball and a marble).

3 Predict what would happen to day and night if Earth did not rotate on its axis.

4 Contrast the motion of Earth around the Sun with the motion of the Moon around Earth.

5 Describe what would happen to Earth's orbit if the Sun's gravity suddenly disappeared.

2.2 Causes of 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 suggest why Earth's tilt on its axis causes different parts of Earth to experience different light intensity.

SC 3: I can predict the season at a particular place on Earth based on Earth's tilt relative to the Sun.

Lesson overview

Seasonal changes are an important part of life on Earth. As seasons change, there are changes in the lengths of day and night, temperature, weather patterns and the environment. 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.

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 2.2.2 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 towards the Sun (Figure 2.2.1). The part of Earth that is tilted towards the Sun receives more direct sunlight and more hours of daylight. Meanwhile, the part of Earth tilted away from the Sun receives less direct sunlight and fewer hours of daylight.

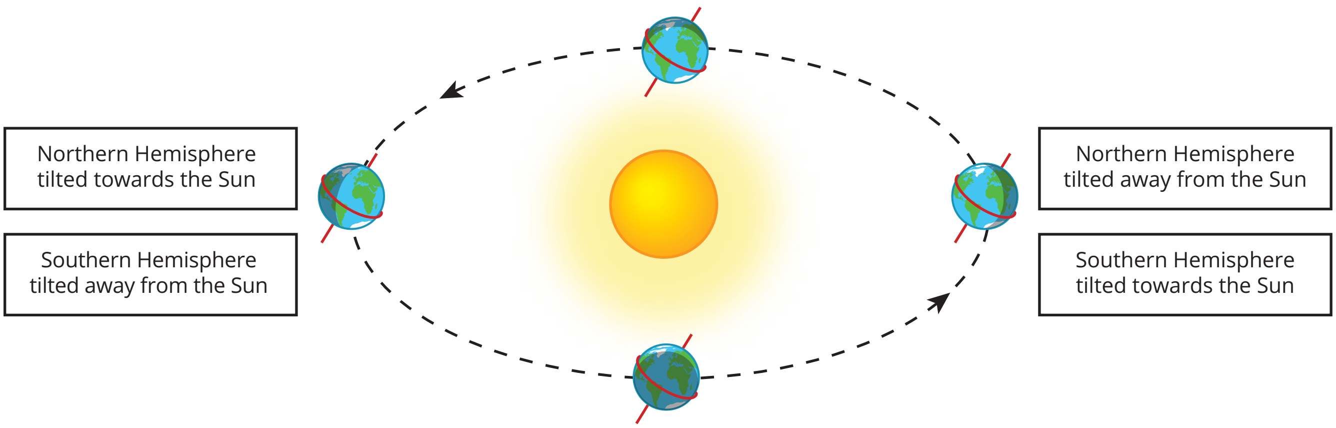


FIGURE 2.2.1 Earth's seasons are caused by its orbit and the tilt of its axis of rotation.

During an Australian summer, the South Pole is tilted toward the Sun and the Sun's path appears higher in the sky. In summer it also takes longer for the Sun to set, creating longer daylight hours. As Earth continues to orbit the Sun, it reaches a point in autumn and again in spring during which neither the South Pole nor the North Pole is tilted toward the Sun. This causes the length of day and night to be equal. During an Australian winter, the South Pole tilts away from the Sun so the Sun appears lower in the sky and sets faster, creating shorter days.

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.

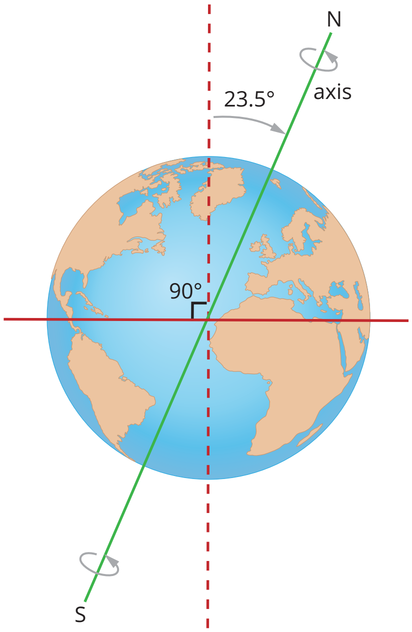


FIGURE 2.2.2 Earth's axis is tilted in space at a fixed angle of 23.5°.

Earth's seasons

Changes in weather, temperature and daylight are noticeable throughout the year (Figure 2.2.3). 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 most hours of daylight and winter being the coldest season with the least hours of daylight. The seasonal changes that a location on Earth experiences depends on that place's position in relation to the Sun's rays.

KEY TERM

season on Earth, summer, autumn, winter, spring; caused by the tilt of a planet's axis

Summer in Australia

Australia is in the Southern Hemisphere. When the Southern Hemisphere is tilted towards the Sun, the Southern Hemisphere experiences summer (Figure 2.2.3). Summer in Australia occurs between December and February. The Sun is higher in the sky during this time and above the horizon for a longer duration, creating higher temperatures and more hours of daylight.

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.

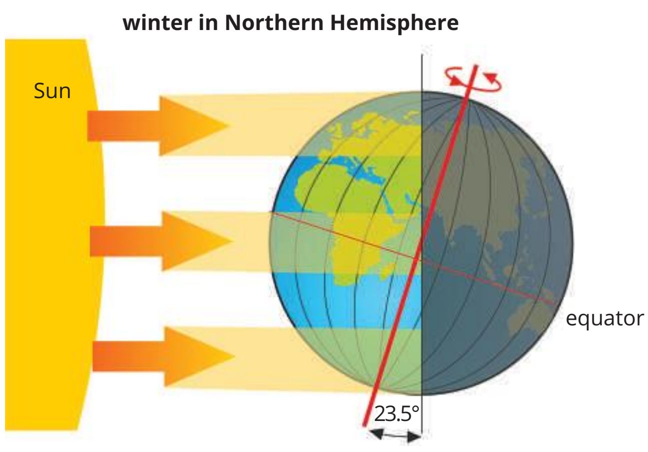


FIGURE 2.2.3 Earth's position during the Southern Hemisphere summer and Northern Hemisphere winter

Winter in Australia

When the Southern Hemisphere is tilted away from the Sun, the Southern Hemisphere experiences winter (Figure 2.2.4). Winter in Australia occurs between June and August. The Sun is lower in the sky during this time and remains above the horizon for a shorter time, creating lower temperatures and fewer hours of daylight. At the same time, the Northern Hemisphere is tilted towards the Sun and experiences summer.

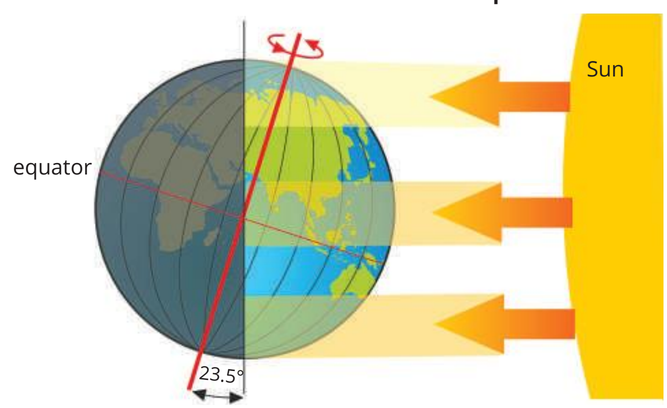


FIGURE 2.2.4 Earth's position during the Northern Hemisphere summer and Southern Hemisphere winter

Autumn and spring in Australia

Spring is the season that follows winter and is caused by the changing orientation of Earth's tilt towards the Sun. In spring, the number of hours of daylight and temperature begin to increase. Spring occurs between September and November in Australia.

Autumn is the season that follows winter and is caused by the changing orientation of Earth's tilt away from the Sun. In autumn, the number of hours of daylight and temperature begin to decrease. Autumn occurs between March and May in Australia.

During mid-spring and mid-autumn, there is a time when the number of hours of daylight and night are equal and neither of Earth's hemispheres tilts more towards the Sun. Temperatures are moderate in spring and autumn.

The season experienced in the Southern Hemisphere is the opposite of the season experienced simultaneously in the Northern Hemisphere. When it is spring in Australia, it is autumn in North America.

SkillBuilder

Graphing seasonal data

Patterns in data

- A pattern is a repeated occurrence or sequence in data. The data is repeated, so patterns can be used to predict observations.
- A trend is when the results are changing in one direction during the time of the recording of data.

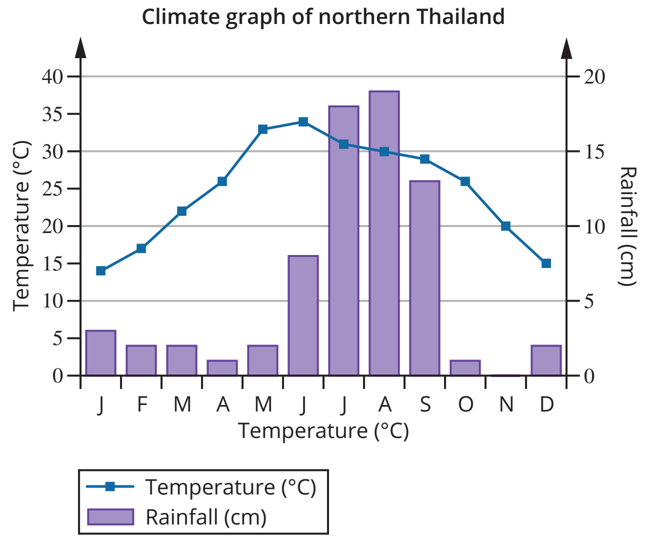
Describing patterns from graphs

1. Look at the overall pattern shown by the changes to the data on the graph.
2. If the change is all in one direction, then the pattern is called a trend.
3. Patterns that are not trends can still be used to describe events and make predictions by analysing the shape of the graph.

Seasonal patterns

1. A seasonal pattern occurs when the results are repeated over a certain amount of time, such as a year.
2. High parts of the graph are called peaks and low parts of the graph are called troughs.

For example, Alex knows that the temperature and rainfall in one year in northern Thailand follows a seasonal pattern. By looking at the rainfall and temperature data from this year on the graph, he can predict when temperatures and rainfall will be at their highest next year. The graph shows that the temperature peaks in June at 33°C and rainfall has a major peak in August at 18 cm.



SC 1 CHECK YOUR UNDERSTANDING

Explain why it is summer in Australia when it is winter in the Northern Hemisphere.

SC 2 I can suggest why Earth's tilt on its axis causes different parts of Earth to experience different light intensity

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.

KEY TERM

equator an imaginary Hemispheres; it that divides Earth into the Northern and Southern Hemispheres; it lies equal distance between the North and South Poles

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 2.2.5. The amount of solar energy received at each pole also changes depending on which hemisphere is tilted towards or away from the Sun.

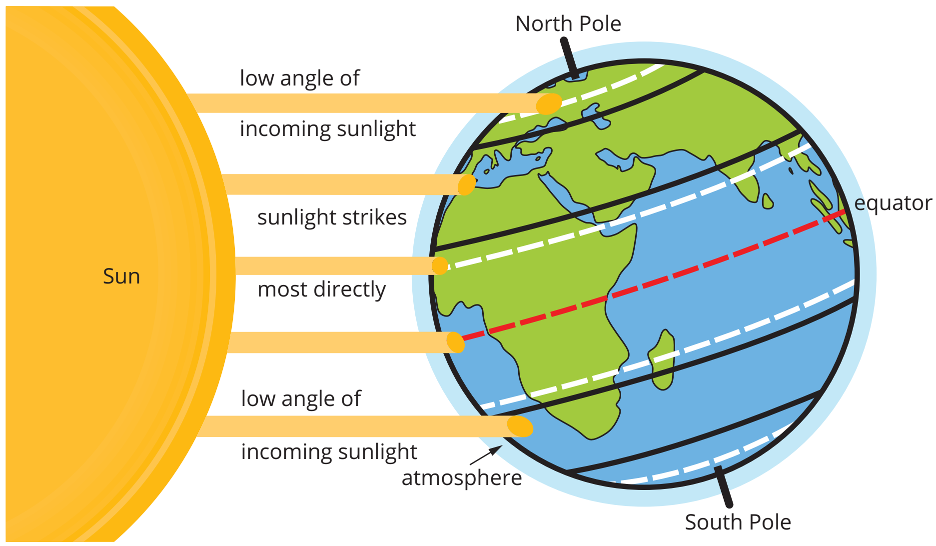


FIGURE 2.2.5 Sunlight strikes Earth's surface at different angles at different positions on Earth.

GO TO
Toolkit sections 3.4, Using line graphs and column graphs and 3.5, Patterns and trends in data

The angle of sunlight and Earth's tilt

The closer to 90° that a location on Earth is to the Sun's rays, 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 2.2.6).

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 towards or away from the Sun for part of the year.

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 capture more energy and produce more electricity. This is why some solar panels can move.

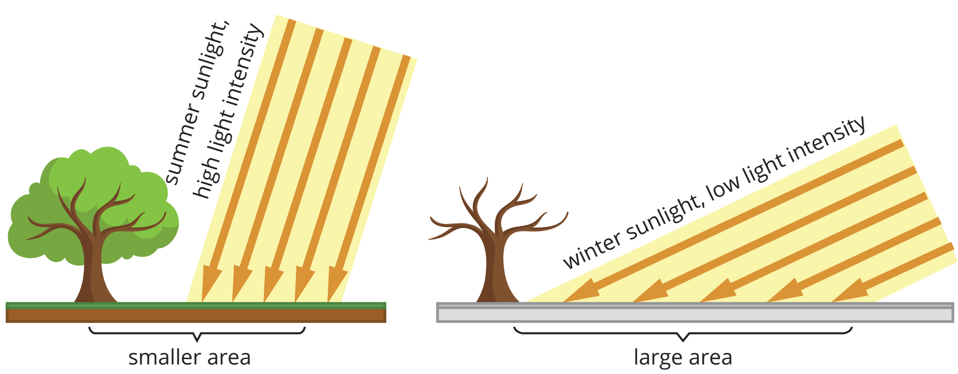


FIGURE 2.2.6 The intensity of sunlight changes throughout the year due to Earth's tilt.

Light intensity and seasons

During winter, the angle of Earth's axis causes the Sun's rays to reach a location at a smaller 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°), 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 2.2.7).

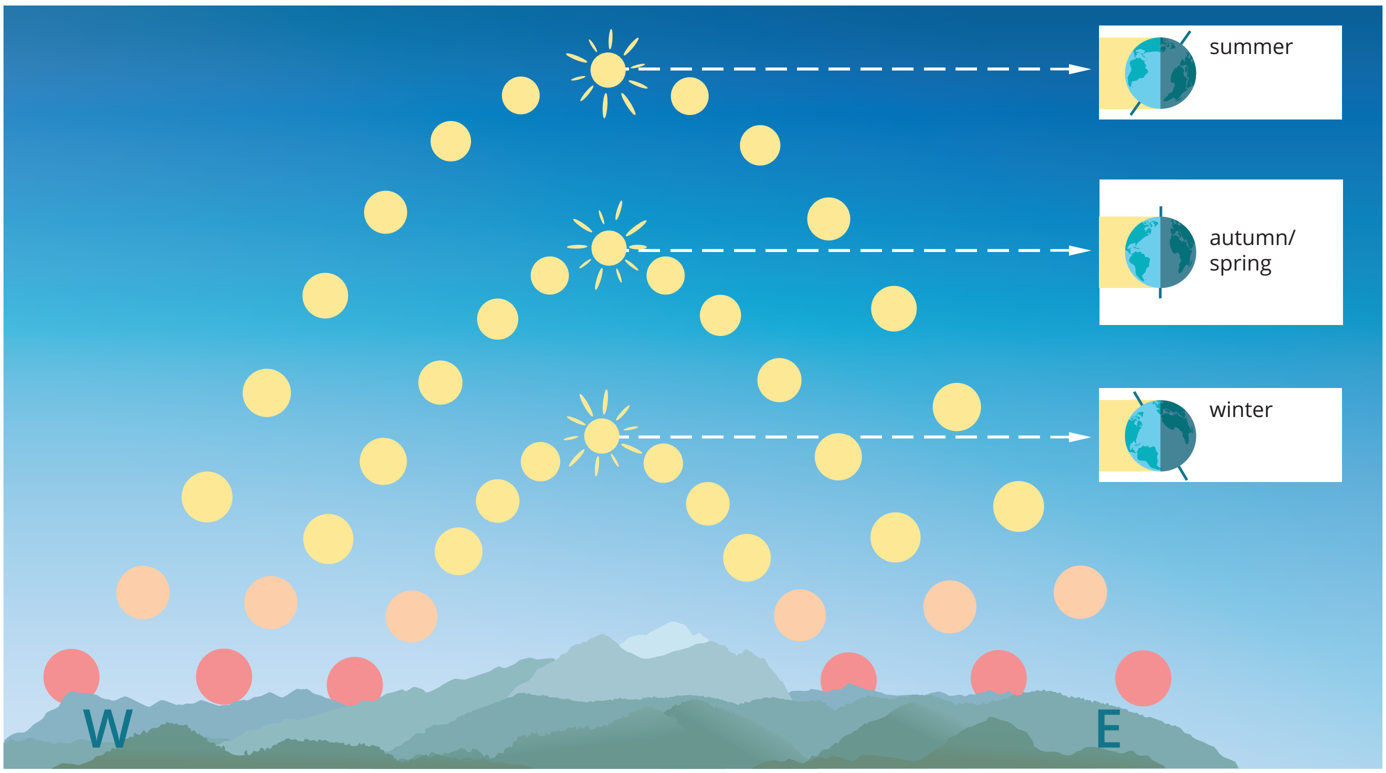


FIGURE 2.2.7 The Sun is higher in the sky in summer and lower in winter, so the light from the Sun is more intense in summer and less intense in winter.

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

During Earth's orbit around the Sun, different parts of Earth experience changes in the amount and intensity of sunlight they receive due to Earth's tilt (Figure 2.2.8).

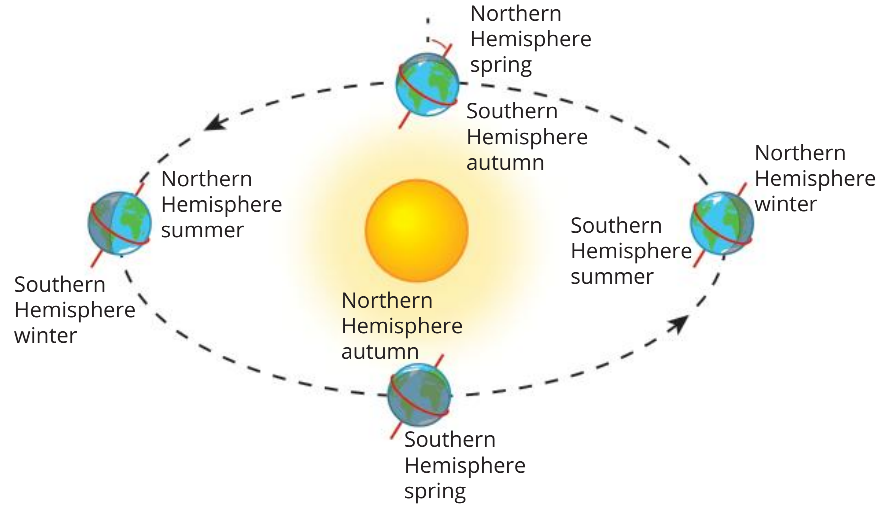


FIGURE 2.2.8 The mid-latitudes experience the greatest variation in the intensity of sunlight so the seasons are most evident there.

This tilt causes seasonal changes. 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 of the equator (Figure 2.2.9).

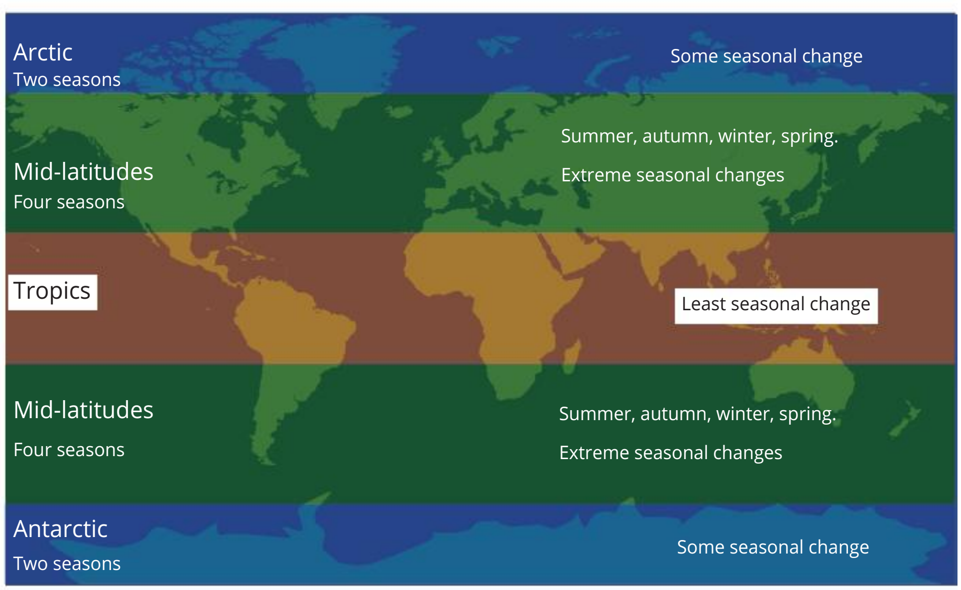


FIGURE 2.2.9 The intensity of sunlight varies with latitude, and this determines how extreme seasonal changes are throughout the year.

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. As Earth completes its orbit of the Sun, the amount of sunlight reaching regions at the equator is relatively constant. 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 high temperatures with changing levels of rainfall in alternating wet and dry seasons (Figure 2.2.10).

FIGURE 2.2.10 Darwin, Australia's most northern capital city, experiences high temperatures all round with two main seasons each year characterised by rainfall as 'wet' and 'dry'.

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 2.2.11).

FIGURE 2.2.11 The same tree during all four seasons

Recall that, when the Northern Hemisphere tilts towards the Sun, mid-latitude places in that hemisphere, such as North America, Europe and Asia, experience summer. Meanwhile, in the mid-latitudes of the Southern Hemisphere, including Australia, South America and New Zealand, the tilt away from the Sun leads to winter. After six months, this situation reverses: the Southern Hemisphere experiences summer as the Northern Hemisphere has winter.

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 (Figure 2.2.12). 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.

FIGURE 2.2.12 During winter in Antarctica the constant darkness is known as a polar night.

When the North Pole is tilted towards 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, the South Pole is tilted away from the Sun during its winter. 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 the:

a Northern Hemisphere is tilted towards the Sun

b 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 2.2.9 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 that experience the most direct sunlight.

2.3 Investigating the changing angle of the Sun

Introduction

The angle of the Sun will change throughout the day due to Earth's rotation. The angle at which sunlight hits the surface of Earth also varies throughout the year because Earth is tilted on an axis. This is shown in Figure 2.3.1. In winter, the Sun never gets as high in the sky as it does in the summer months.

In this practical investigation, you will explore how Earth's changing tilt can be simulated through experiments to understand the different warming effects of sunlight at different angles.

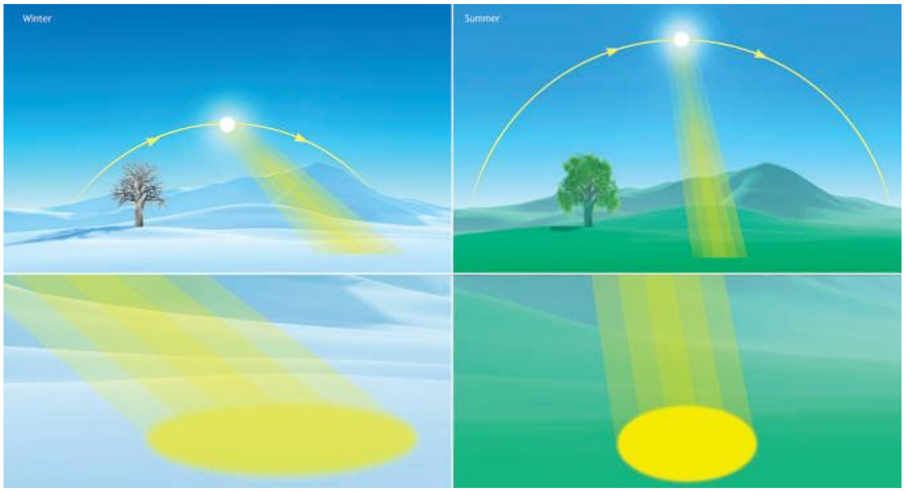


FIGURE 2.3.1 When the Sun is higher in the sky, sunlight is more intense.

Background

The position of the Sun in the sky will change both during the day and during the year. The angle at which sunlight hits Earth can be measured by imagining a straight line drawn from the Sun to a place on the surface of Earth. The angle is measured between this line and Earth's surface.

Note that the angle of sunlight at the equator is larger (more direct) throughout the year than the angle of sunlight hitting Earth's surface at the poles (Figure 2.3.2).

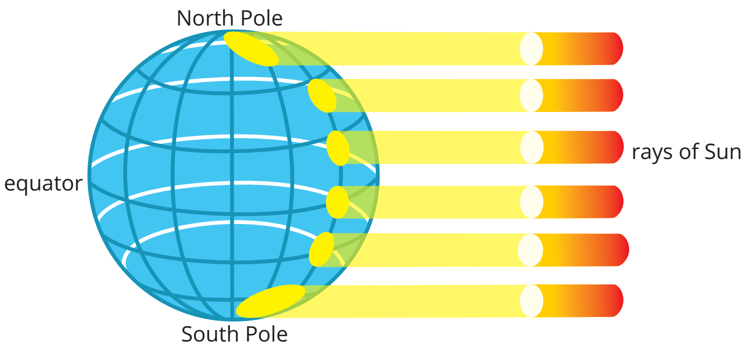


FIGURE 2.3.2 Sunlight hits Earth's surface at 90° in some places and at smaller angles in others.

Learning intention

To be able to use equipment to model the effect of the angle of the Sun on surface temperatures

Success criteria

SC 1: I can set up an experiment that models the changing angles of sunlight.

SC 2: I can make accurate measurements with a thermometer.

SC 3: I can analyse data to test a cause-and-effect relationship.

Aim

To use a model to test whether the angle at which sunlight hits Earth affects the surface temperature on Earth

GO TO
Toolkit section 1.3, Hypotheses and predictions

Hypothesis

Write a hypothesis for your investigation.

Prediction

Read the method and write a prediction for what will be observed in the experiment.

SAFETY NOTE

- The lamp will get very hot so avoid touching it.

Materials

- warm lamp (such as a microscope lamp)
- 2 thermometers
- 2 blocks of wood
- black plastic
- sticky tape

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 results table like the table on the next page to record your results.
2. Cut out two small identically sized sheets of black plastic and tape them onto wooden blocks so that they make pockets.
3. Secure a thermometer in each pocket, ensuring that it is touching the plastic sheet. Tape the thermometer to the board to secure it.
4. Place the two blocks the same distance from the lamp, as shown in the diagram in Figure 2.3.3.
   - Block A: Lay the block flat on the desk so that the light from the lamp falls on it at an angle.
   - Block B: Use some books to position the block at an angle to the desk so that the light falls directly on it.

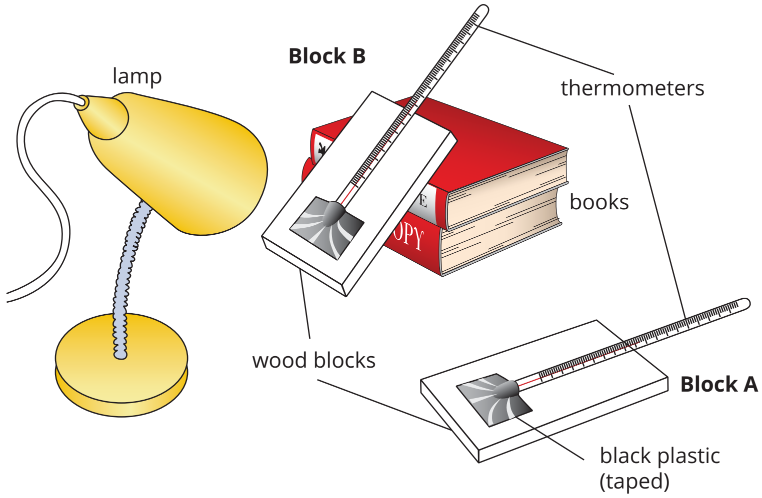


FIGURE 2.3.3 The materials set up for the investigation

5 Estimate the angle of the light to the blocks of wood.

6 Turn on the lamp and record the temperature at each block for at least 5 minutes.

Results

Record your results in a table like this.

Time (minutes)	Block A Angle of light = indirect Temperature, *T* (°C)	Block B Angle of light = direct Temperature, *T* (°C)
1		
2		
3		
4		
5		

Conclusion

Write your conclusion by answering the following questions.

1 Identify which block (A or B) modelled the surface of Earth in summer and which block modelled the surface in winter.

2 Describe whether the results of this experiment support the idea that there is a cause-and-effect relationship between the angle of sunlight and the temperature of the surface of Earth.

Evaluation

Describe how you were able to ensure the accuracy of your measurements in this experiment.

GO TO
Toolkit section 4.1, Evaluating investigations

2.4 Seasonal calendars

Learning intention

To understand seasonal calendars used by First Nations Australians

Success criteria

SC 1: I can describe how a group of First Nations Australians organise their seasonal calendar.

SC 2: I can explain how a group of First Nations Australians use a seasonal calendar to make predictions.

KEY TERMS

Country a term used by First Nations peoples to describe the lands, waterways, seas and skies they have a cultural connection to. The term contains complex ideas about identity, family, language, spiritual belief and law.

constellation a group of stars that form a recognisable pattern in the night sky

Lesson overview

First Nations Australians have long held local knowledge about **Country**. Country, in this context, signifies the importance and status First Nations communities give to the land, waters and sky. They are not just resources to be used, bought or sold; it is a living, breathing entity. First Nations Australians believe that Country talks to us, and you can hear its messages if you know how to connect appropriately.

Seasonal changes are just one example of this communication from Country (Figure 2.4.1). Over many generations, First Nations groups have developed calendars of seasonal changes that use their relationship with the natural environment, observation of the night sky and understanding of plant and animal cycles. In this lesson, you will learn about the development of First Nations calendars and how they are used.

FIGURE 2.4.1 Natural cycles, such as the flowering of plants, provide evidence of changing seasons.

SC 1 I can describe how a group of First Nations Australians organise their seasonal calendar

Seasonal calendars

Different places on Earth experience different seasons. A Western model of spring, summer, autumn and winter, for example, does not reflect the seasons experienced in tropical regions near the equator. The Top End of Australia has a consistent temperature throughout the year with large seasonal rainfall variation. Here, there are often only two seasons described: wet and dry. In contrast, throughout Australia, First Nations seasonal calendars are localised to different regions and are shaped by the patterns in the environment and climate in that region.

Specifically, the seasonal calendars of First Nations Australians are informed by environmental events, such as changes in weather, water supply, animal behaviour and plant life cycles. They are also influenced by the appearance of certain **constellations** in the night sky. First Nations peoples have been observing the sky for tens of thousands of years, allowing them to understand associations between astronomical changes and changes in the landscape on Earth. This knowledge is passed down through generations through storytelling.

Indigenous astronomy

Kirsten Banks is a Wiradjuri **astrophysicist** and **science communicator** who studies Indigenous astronomy. Through her work she has learnt about Indigenous Knowledge systems and how different constellations can be used for navigation, to identify what food is available and to recognise when the weather is going to change. Kirsten uses storytelling and contemporary mediums, such as video, to share Indigenous Knowledge with a wide audience. One of the constellations that first inspired Kirsten's work was the Emu in the Sky.

Emu in the Sky

One of the most significant constellations to many First Nations groups across Australia is the Celestial Emu (sometimes called the 'Emu in the Sky'). This constellation is made up of the dark spaces in the Milky Way, rather than its stars, and its position in the night sky is linked to many **Creation stories**. The alignment and visibility of the Celestial Emu changes throughout the year. According to many First Nations groups, these changes align with the emu's life cycle on Earth, providing information about the best time to harvest eggs for food.

KEY TERMS

astrophysicist a scientist who studies the behaviour and physical properties of objects and events in space

science communicator a person who informs others who are normally non-experts about scientific findings, often with the aim of raising public interest in science

Creation stories stories that explain the origins of the universe, the rules for living and the relationship of people to each other and the environment; also known by many as Dreaming stories

Breeding season

When the Celestial Emu is seen rising in the sky during April and May (Figure 2.4.2), this indicates the start of the emu breeding season. Breeding season is the best time to sustainably harvest eggs that have just been laid. Not all eggs from a nest are collected; some are left to ensure future generations of emu.

FIGURE 2.4.2 The Celestial Emu rises in the east.

Nesting season

In June and July, the constellation appears horizontal in the sky (Figure 2.4.3), indicating that male emus are sitting on eggs in the nests. Chicks have developed in the eggs by this time and therefore harvesting ceases.

FIGURE 2.4.3 The Celestial Emu sits sideways in the sky at the time when emus sit on their eggs.

FIGURE 2.4.4 Emus hatch in spring.

Hatching season

From August to September, the Celestial Emu shifts to a vertical position in the sky, which signifies the male emus rising from the nests and the chicks hatching (Figure 2.4.4). The male emus rear the chicks at this time and so there are no eggs to collect.

SC 1 CHECK YOUR UNDERSTANDING

Describe some of the environmental knowledge or observations that were used by First Nations people to develop their seasonal calendar.

SC 2 I can explain how a group of First Nations Australians use a seasonal calendar to make predictions

Fire and seasons calendar

Different seasons and seasonal calendars are important to different groups of First Nations Australians because they provide local information about their environment. This information includes the best times to do, or not do, certain things such as use fire, travel, hunt, fish and collect food and other resources. They are developed through detailed observation of the environment and night sky over a long period of time and knowledge is passed down from generation to generation.

For example, members of the Banbai Nation, 35 km north-east of Guyra in northern New South Wales, use a calendar to divide the year into seasons for fire management. Fire is critical to the sustainability of the landscape and the ability to predict when to take certain fire management actions is essential in caring for Country. Cool burning or cultural burning is a management practice that typically involves lighting small fires, and monitoring them on foot, to clear undergrowth and protect the tree canopy (Figure 2.4.5). Cool burning needs to happen in the right place at the right time of year. If burning occurs when it is too hot and windy, fires will become too intense and get out of control, destroying the tree canopy; if it is too cold, burning won't be possible.

FIGURE 2.4.5 First Nations Australians used cool burning to manage the landscape.

The Banbai Fire and Seasons calendar

The Banbai Fire and Seasons calendar was developed using long-term Indigenous Knowledge of local **ecological** and cultural seasonal events, as well as recent ecological research.

Culturally significant changes in nature signify when the seasons are changing and when it is a good time to burn.

KEY TERM

ecological a description of something that relates to ecosystems or interactions between living things and their environment

The calendar draws on various indicators, including animal migration, breeding and activity; plant flowering and fruiting events; availability of bush tucker species for harvest; and changes in weather patterns. A simplified version of the Banbai Fire and Seasons calendar is presented in Table 2.4.1.

TABLE 2.4.1 The Banbai Fire and Seasons calendar

Season	Weather and fire conditions
Wildfire time (November to March)	Wet and hot, becoming warm Wildfires occur naturally; a dangerous time to burn.
Grass cures (dries out) (April to May)	Dry, becoming cool Once grass cures, it is easier to burn.
Burning time (May to June)	Dry and cold to frosty Low intensity fire time; a good time to burn.
Too cold (July)	Freezing and windy Too cold to burn.
Burning time (August to September)	Cold, becoming warm Low intensity fire time; a good time to burn if it is not windy.
Risky time (October)	Hot and windy Getting too hot and windy; a risk that fires won't go out.

SC 2 CHECK YOUR UNDERSTANDING

Identify some activities that First Nations people would have done based on their seasonal calendar.

Lesson review

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

1 Describe a seasonal calendar like those used by First Nations Australians. Include a description of how they can be used.

2 What are the differences between the seasonal calendar of a group of First Nations Australians and the Western calendar used today?

3 Think about how a seasonal calendar is organised.
   a Why do First Nations Australians use a seasonal calendar?
   b How does a seasonal calendar help First Nations Australians in their daily lives?
   c Explain how the seasonal calendar is linked to environmental changes.

4 Consider the example of the emu and how First Nations Australians were able to predict their behaviour and breeding cycle.
   a What were the observations that could be made at night that let First Nations people know what emus would be doing?
   b How could the observations you described in part a be used?
   c What other observations might you look for if you were not able to see the night sky due to long periods of cloudy weather?

2.5 Tides

Learning intention

To understand how the position of Earth and the Moon causes tides

Success criteria

SC 1: I can describe how the rotation of the Moon relates to its orbit around Earth.

SC 2: I can explain how the forces of gravitational attraction of the Moon and Sun affect water in Earth's oceans.

SC 3: I can explain the cause of neap and spring/king 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. This is because of the changing tide; the level that the sea rises and falls over the course of a day (Figure 2.5.1). The changing tides are caused by the gravitational pulls and the rotations of the Moon, the Sun and Earth. In this lesson, you will learn how the positions and interactions of Earth, the Sun and the Moon cause tides.

FIGURE 2.5.1 High and low tide on a rocky shore

SC 1 I can describe how the rotation of the Moon relates to its orbit around Earth

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 Moon's orbit takes about the same time as its rotation, a little over 27 days. As the rotation and orbit time are the same, the same side of the Moon always faces 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.

The Moon in action

You may have heard about 'the dark side' of the Moon. This expression isn't quite accurate as both sides of the Moon experience the same amount of time in sunlight. Figure 2.5.2 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.

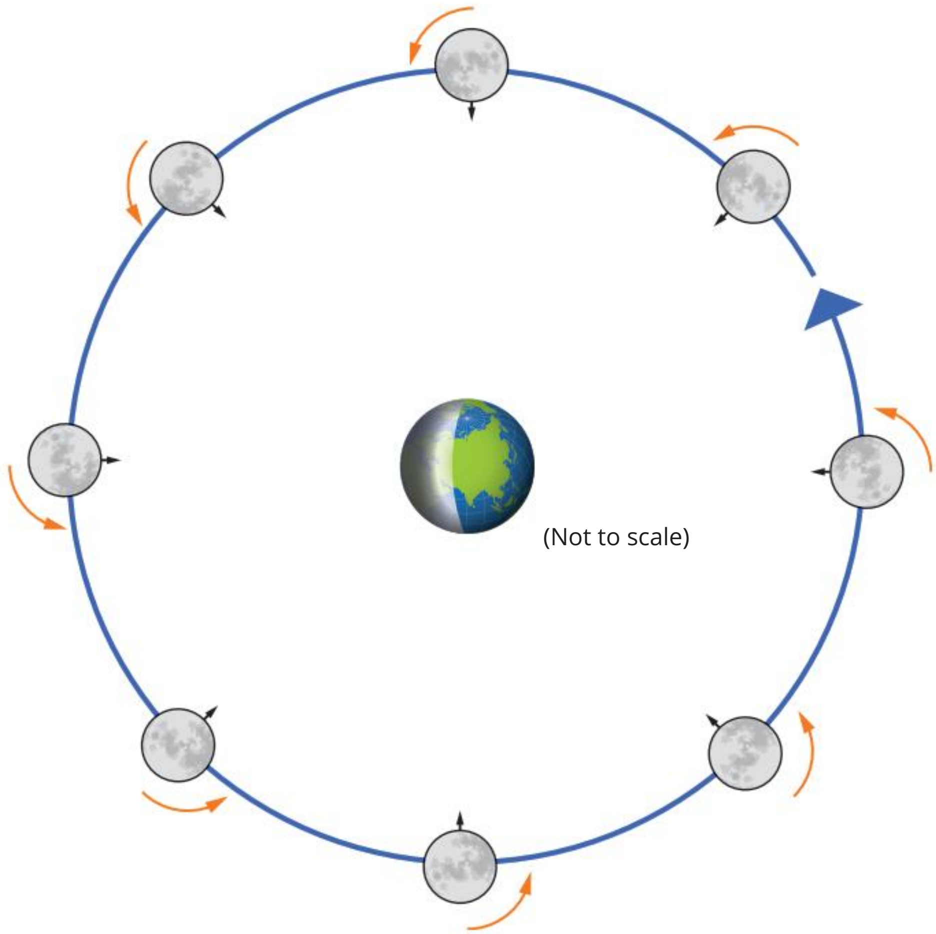


FIGURE 2.5.2 The Moon orbits around Earth approximately every 27 days and rotates once on its axis in that time, so only one side of the Moon (the near side) faces Earth. During one orbit, the far side of the Moon is not seen from Earth. The whole surface of the Moon spends time both in sunlight and in shadow so there is no dark side of the Moon. An arrow at one location on the Moon is shown to highlight how the Moon rotates as it orbits Earth.

SC 1 CHECK YOUR UNDERSTANDING

Explain the relationship between the Moon's rotation and its orbit around Earth.

Scifile

The Moon in action

You may have heard about 'the dark side' of the Moon. This expression is not quite accurate as both sides of the Moon experience the same amount of time in sunlight. Figure 2.5.2 shows the Moon's orbit around Earth and its rotation on its axis. As the Moon orbits Earth, one side of the Moon (the near side) continually faces Earth.

SC 2 I can explain how the forces of gravitational attraction of the Moon and Sun affect water in Earth's oceans

KEY TERMS

tide the rise and fall of water levels in large bodies of water such as oceans 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 an object

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 2.5.1 shows the same shore at high (left) and at low tide (right).

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 across all of Earth's surface—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 towards the Moon, causing the water in oceans on the side of Earth nearest the Moon to bulge outwards (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 2.5.3).

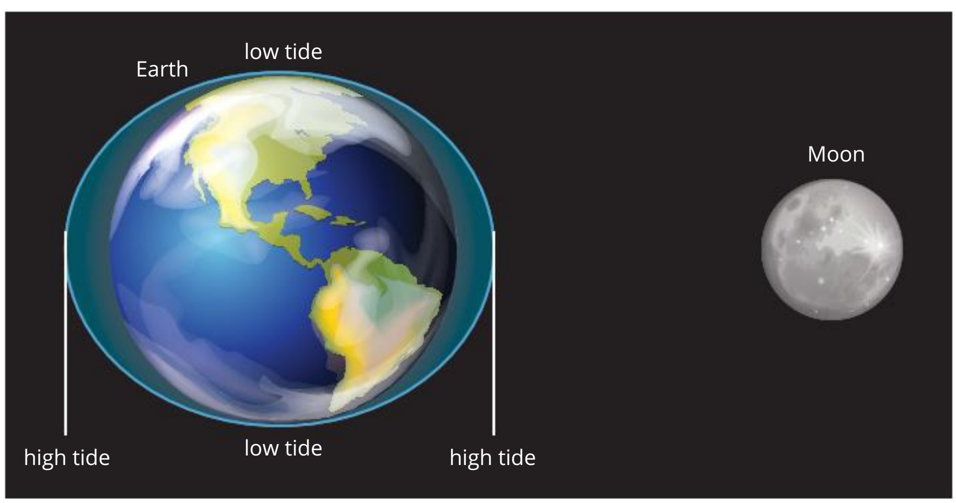


FIGURE 2.5.3 Two high and two low tides occur each day as Earth rotates on its axis, caused by the gravitational force of the Moon.

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).

SC 2 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 3 I can explain the cause of neap and spring/king tides

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 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 when 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 tides

Spring tides, or king tides, occur twice a month when the Moon lines up with Earth and the Sun (Figure 2.5.4). 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.

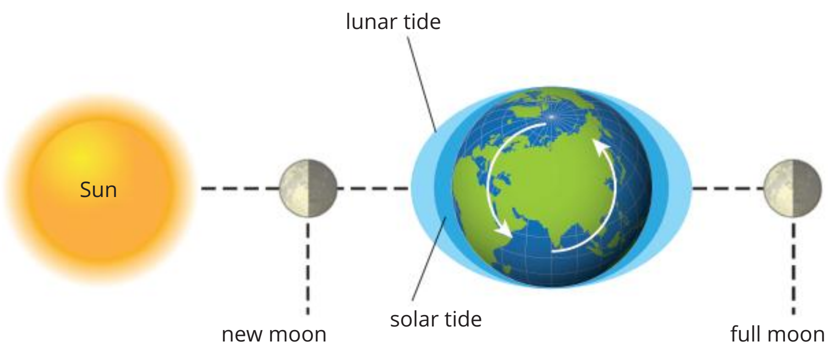


FIGURE 2.5.4 Spring tides occur at full and new moons; at these times, the gravitational attraction of the Sun and the Moon combine to increase the difference between low tide and high tide.

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 2.5.5). 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.

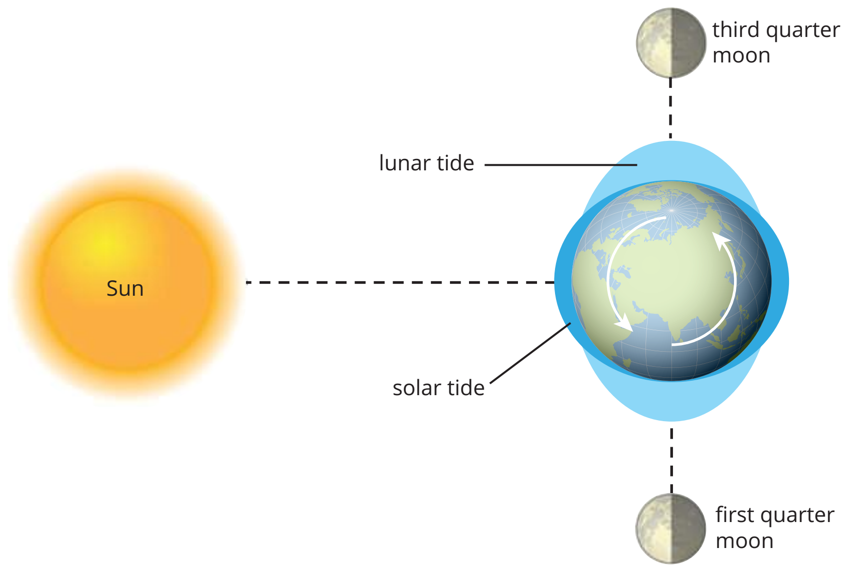


FIGURE 2.5.5 Neap tides occur when the Moon's gravity pulls at right angles to the Sun's.

SC 3 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.

2.6 Effects of tides

Lesson overview

The movement and position of Earth, the Sun and the Moon cause predictable tidal changes. Tides refer to the rising and falling of water levels in large bodies of water, such as oceans and lakes. Tides are mostly caused by the Moon, although the Sun has an influence too. As the Moon orbits Earth, its gravitational pull affects the water, causing it to 'bulge' on the side of Earth closest to the Moon, as well as on the side furthest away.

Tides play a crucial role in marine and coastal ecosystems, influencing various events along coastlines. Recording data, observing tidal patterns and making predictions help society to plan activities at sea and on the shore. In this lesson, you will learn about observing tidal data, the effects of tides and their impact on society.

Learning intention

To understand how information about tides is used in society

Success criteria

SC 1: I can use patterns in tidal data to make predictions.

SC 2: I can describe ways people use information about tides in society.

SC 3: I can describe how a group of First Nations Australians use tidal patterns to predict the best time for foraging and fishing activities.

SC 1 I can use patterns in tidal data to make predictions

Tidal data

As the positions of Earth, the Sun and the Moon change, the gravitational forces acting on Earth's oceans change with them. The result can be seen as variations in the levels of sea water or tidal changes. The movement of Earth, the Sun and the Moon, and their influence on Earth's oceans, is regular and predictable. This allows us to calculate the times and heights of tides at a particular location. Other factors such as the shape of a shoreline and local wind and weather conditions also affect tides, so actual tide measurements are used to establish patterns as well (Figure 2.6.1).

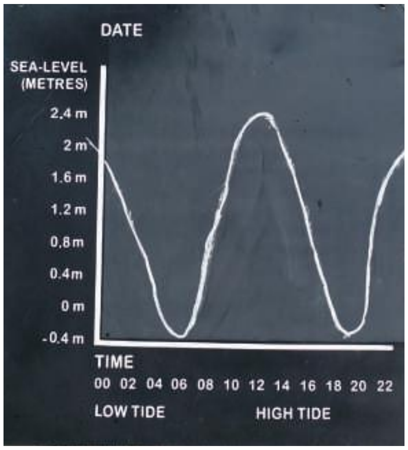


FIGURE 2.6.1 The tides cause the surface of the ocean to rise and fall twice a day.

Tide levels

Generally, four different tides occur within a day: two high tides and two low tides. Neap and spring tides occur every moon cycle, about twice every month. The positions of Earth, the Sun and the Moon determine the times when these tidal changes occur.

High tides and low tides

High tide and low tide refer to the periodic rising and falling of water levels in large bodies of water, such as oceans and seas, caused by the gravitational forces of the Moon and the Sun on Earth. The specific timing and **magnitude** of these tides can vary according to geographical location, local **topography** and other factors.

KEY TERMS

magnitude a measure of the size or strength of something

topography the hills, valleys, rivers and other physical features of the landscape

Neap tides and spring tides

KEY TERM

lunar cycle the period of 27.3 days that it takes for the Moon to orbit Earth

The terms 'neap' and 'spring' can be misleading, as neap tides are not weaker in the spring season, nor are spring tides stronger in spring. In fact, these terms refer to the increased or decreased gravitational forces exerted by the Sun and the Moon on Earth's oceans during specific stages of the **lunar cycle**.

Table 2.6.1 explains the key features of these daily and monthly tides.

TABLE 2.6.1 Features of tides

Tide	Features
High tide	• High tide occurs when the gravitational pull of the Moon is strongest on the side of Earth facing the Moon, leading to higher water levels along the coastline. • The gravitational force of the Sun contributes to high tide when it is aligned with the Moon. • High tide occurs approximately twice a day, roughly every 12 hours and 25 minutes, which corresponds to the time it takes for a location to complete a full rotation relative to the Moon.
Low tide	• Low tide occurs at the locations on Earth not experiencing a high-tide bulge. • The reduced gravitational pull causes a temporary recession of the sea, exposing more of the shoreline. • Low tide also occurs approximately twice a day, between the periods of high tide.
Neap tide	• Neap tides occur during the first and third quarters of the lunar cycle when the Sun, Earth and the Moon form a right angle. • The gravitational forces of the Sun and the Moon partially cancel each other out, resulting in weaker tides. Neap tides are characterised by lower high tides and higher low tides. • Neap tides occur about seven days after spring tides.
Spring tide	• Spring tides occur during the new moon and full moon phases when the Sun, Earth and the Moon are aligned. • The gravitational forces of the Sun and the Moon combine, resulting in stronger tides. Spring tides are characterised by higher high tides and lower low tides. • Spring tides occur about twice a month, around the times of the new moon and full moon.

Tidal range

The difference between high tide and low tide is called the tidal range (Figure 2.6.2).

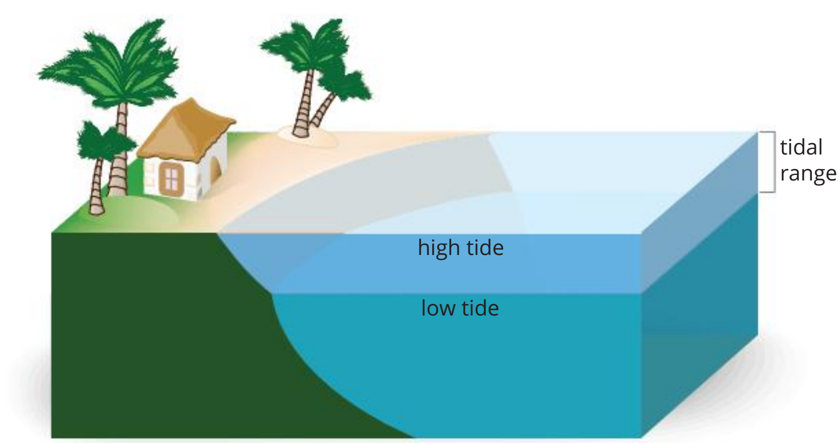


FIGURE 2.6.2 The tidal range in ocean tides

Seeing patterns in the daily tides

The graph in Figure 2.6.3 shows the time and height of two high tides and two low tides that occur at a single location over the course of 24 hours. As you can see, high tide in the morning occurs at 1:04 am at a height of 1.77 m; low tide in the morning occurs at 8:13 am at a height of 0.49 m. High tide in the afternoon occurs at 2:18 pm at a height of 1.31 m; low tide during the night occurs at 7:42 pm at a height of 0.77 m.

From this example, you can see that two low tides and two high tides occur. The exact time between tides varies with location and over time. As the Moon orbits Earth, the tide time gets later with each passing day.

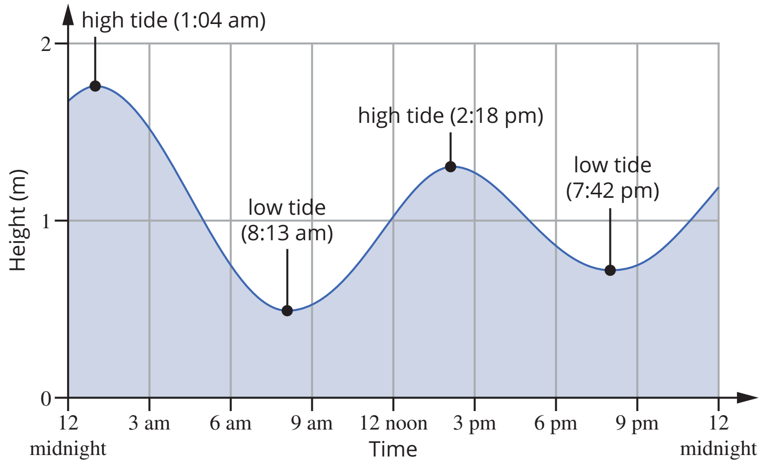


FIGURE 2.6.3 A graph of the height of the ocean's surface over 24 hours

Tides across the month

The graph in Figure 2.6.4 shows the height of high tides and low tides over 28 days for a single coastal location.

Spring tides are shown by the largest tidal range between high and low tides in a day. Neap tides are shown by the smallest tidal range between high and low tides in a day.

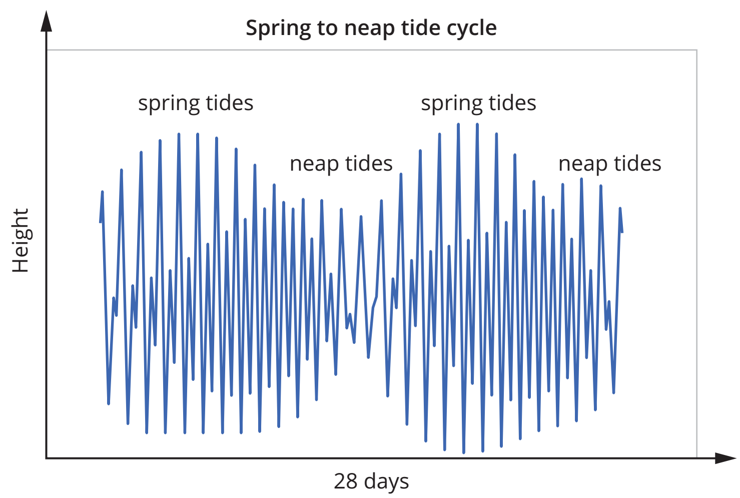


FIGURE 2.6.4 A graph of the variations in the height of the ocean's surface over 28 days

Tide charts

Tide charts, or tide tables, are used to predict daily times and heights of tides for a specific location. For most coastal locations, tide charts are publicly available online, in newspapers and in local radio and television broadcasts. Tide charts always include the date, times and heights for low tides and high tides for a particular site, though the chart format and units may vary.

The tide chart in Table 2.6.2 shows tide times and heights over three days at Fort Denison, a ferry terminal in Sydney Harbour. It provides the times and heights for the first high tide, the first low tide, the second high tide and the second low tide each day.

TABLE 2.6.2 Tide times at Fort Denison, Sydney Harbour in May 2023

Sydney (Fort Denison) latitude 33°51′S longitude 151°14′E		
Date	**Time**	**Height (m)**
12 May 2023, Friday	1:04 am	1.77
	8:13 am	0.49
	2:18 pm	1.31
	7:42 pm	0.77
13 May 2023, Saturday	2:15 am	1.72
	9:15 am	0.48
	3:27 pm	1.38
	9:00 pm	0.75
14 May 2023, Sunday	3:26 am	1.70
	10:11 am	0.46
	4:26 pm	1.48
	10:13 pm	0.69

SC 1 CHECK YOUR UNDERSTANDING

Read Table 2.6.2 and predict the approximate time and height of the first high tide on 15 May.

SC 2 I can describe ways people use information about tides in society

KEY TERMS

ecology the study of how organisms interact with each other and their non-living environment

economy a system in which goods and services are produced and sold

commerce buying and selling goods or services

Tides and ecology

Tides play an important role in the **ecology**, culture and **economy** of coastal locations. Predicting tides and interpreting tidal information is essential for anyone who uses the sea for travel, research, recreation, livelihood or **commerce**. Some of the ways people use information about tides are discussed below.

SCIENCE IN SOCIETY

Protecting Australia's coastlines

The positions of Earth and the Moon cause tides, which have a significant impact on coastal management. Tides influence the shape and stability of coastlines, affecting erosion, sediment transport, and the formation of coastal features such as beaches and estuaries. Coastal managers use knowledge of tides to plan and implement measures that protect coastal areas from erosion and flooding. For example, in Australia, the New South Wales Government has developed a Coastal Management Program that includes strategies for managing the impacts of tides and sea-level rise.

Understanding tides is also crucial for the construction of coastal infrastructure, such as ports, marinas and sea walls. Engineers need to consider tidal patterns when designing these structures to ensure they can withstand the forces of the sea (Figure 2.6.5). Accurate tidal predictions help in planning construction activities, such as dredging and piling, which need to be carried out at specific tidal conditions. By understanding how the positions of Earth, the Moon and the Sun cause tides, coastal managers and engineers can make informed decisions that protect coastal communities and ecosystems.

FIGURE 2.6.5 Coastal structures and barriers like these concrete and rock walls need to be designed using a detailed knowledge of the tides. Similarly, submerged structures would need to withstand the forces exerted by the tides.

Navigation and operations

Tides affect the flow and depth of water at the coast. Ships and boats require enough water to stay afloat without getting stuck on the ocean floor. Therefore, navigating ports with shallow waters must ensure vessels arrive and leave at high tide to stop them from running aground. Ports with bridges also use tidal information to ensure that ships can pass under the bridge safely (Figure 2.6.6). In some ports, large ships are only able to fit under a bridge at low tide.

FIGURE 2.6.6 This cargo ship is passing under the bridge at low tide to ensure there is enough clearance.

Fishing

Tidal currents are the movement of water due to the tides. Tidal currents can influence fish activity, so it is important to observe the tides, currents and trends in fish behaviour to optimise fishing efforts (Figure 2.6.7). Fishing at the wrong time can mean wasting time and resources, resulting in a small catch.

The best time to fish depends on the target species, tide and location. In some places, it may be best to fish for large species between high tide and low tide when the tidal current increases the movement of small fish and crustaceans, attracting larger fish.

FIGURE 2.6.7 Tides can affect fishing conditions.

FIGURE 2.6.8 The best time for recreational activities at the beach is affected by the tides and tidal currents.

KEY TERMS

ecosystem a system formed by organisms interacting with each other and their non-living surroundings
organism a living thing
renewable energy source a source of energy that can be replaced after it is used, such as solar and wind energy

Recreation

Tides affect many recreational activities at the beach such as surfing, diving, swimming and exploring rock pools (Figure 2.6.8). The optimal tide conditions depend on your location and the activity you want to do. For snorkelers and divers, the depth and accessibility of a dive site may change between high and low tides. Visibility will improve with reduced tidal currents. Tide information is also important for safety. Some areas of the shore may be accessible at low tide but are cut off at high tide. Tidal changes can also cause dangerous currents.

Ecology

Tides affect marine **ecosystems**, influencing the types of **organisms** in the sea and on the shore. Tidal environments are regularly submerged and exposed during the tidal cycle. Native organisms are specially adapted to these changing conditions. Disruption of tidal influences, for example, those caused by storms (Figure 2.6.9), can therefore have a significant effect on such organisms, which rely on the tidal cycles for breeding or growth.

Energy

Because of their predictability, tides have the potential to be used as a **renewable energy source**. The flow of ocean water between high tide and low tide generates a force that can be converted into electricity. Generating electricity from tidal energy involves turbines, like wind turbines, that are moved by tidal current (Figure 2.6.10). These turbines are like the propellers of an aeroplane but they are moved by the water. Using tidal turbines is an extremely clean, sustainable and efficient way to generate energy.

FIGURE 2.6.9 Storm surge damage and a sand bank were washed away just metres from homes in Sydney.

FIGURE 2.6.10 Tidal currents can turn turbines, which are used to generate electricity.

SCIENCE IN SOCIETY

Tides and renewable energy

Tidal power harnesses the energy of moving water caused by tides to generate electricity (Figure 2.6.11). This form of renewable energy is predictable and reliable, as tides follow regular and measurable patterns. In Australia, the potential for tidal energy is being explored in areas with strong tidal currents, such as the Kimberley region in Western Australia and the Torres Strait in Queensland.

Tidal energy projects require detailed information about tidal patterns, including the height and timing of tides. Engineers use this information to design and position tidal turbines and other infrastructure. By understanding tides, they can maximise the efficiency of tidal power systems and reduce the environmental impact. Tidal energy has the potential to contribute to Australia's renewable energy mix, providing a clean and sustainable source of electricity.

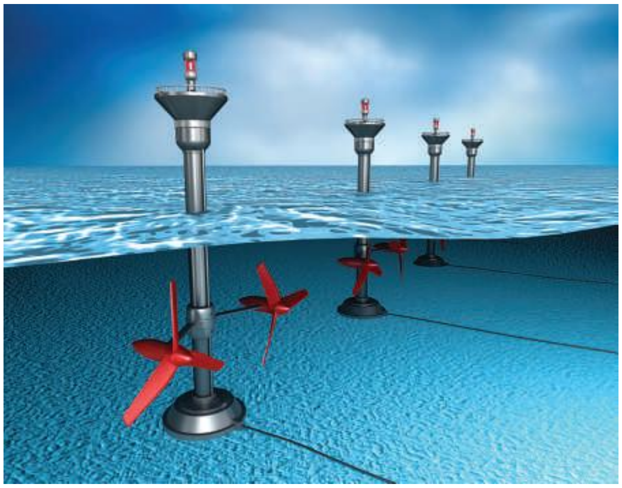


FIGURE 2.6.11 The energy in the movement or water can be transformed into electricity by tidal turbines like those shown. As the movement of water changes direction, the turbines change direction to continue to transform the energy of moving water into electricity.

SC 2 CHECK YOUR UNDERSTANDING

Describe two ways that people use tidal information when planning activities in coastal areas.

SC 3 I can describe how a group of First Nations Australians use tidal patterns to predict the best time for foraging and fishing activities

KEY TERM

forage to search for something (usually food) over a wide area

Knowledge of tidal patterns

First Nations Australians have a strong and long-standing connection to the sea and tidal environments. Their knowledge systems also link the changing phases of the Moon to the changing tides. The Yolngu people of East Arnhem Land, for example, have noticed that the Moon appears to fill up and empty as it moves across the horizon. According to their teachings, tides reach their peak when the Moon is full or new, setting or rising. In contrast, tides are at their lowest when the Moon is near its zenith (high in the sky), aligning with the gravitational effects of the Moon on Earth.

Bardi Peoples of the Dampier Peninsula

The Bardi peoples of the Dampier Peninsula, Western Australia (Figure 2.6.12) use their knowledge of the tides to travel between islands. During neap tides, these journeys are safe to make as the tidal range is reduced. At low tides, they are also able to **forage** for and collect food, such as fish, and other resources like pearls from around the peninsula.

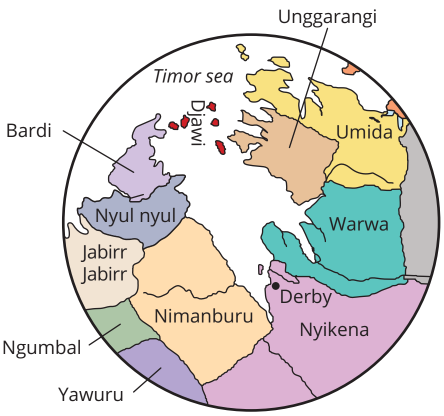


FIGURE 2.6.12 Map showing the Bardi peoples' traditional lands, a First Nations community near Derby, in Western Australia

The Tommeginer People

In north-west Tasmania, the Tommeginer People have constructed tidal fish traps in coastal areas. A low wall of boulders is built in the **intertidal zone** so that when it is high tide the boulders are submerged and fish can swim over them. As the tide goes out, the boulders become visible and the fish become trapped in the shallow waters that remain where they are more easily caught (Figure 2.6.13).

FIGURE 2.6.13 Fish traps constructed by the Tommeginer people

Brewarrina Fish Traps

The Brewarrina Fish Traps, are a series of interconnected stone **weirs** and pools, that rely on tidal movements in the Barwon River, New South Wales, to trap and catch fish during different seasons. As high tide approaches, fish move into the traps in the **estuarine** section of the river, following the natural flow of water. When the tide recedes, the fish become confined within the weirs and pools, making them easier to catch.

These fish traps are believed to have a history dating back 40 000 years. Their ingenuity lies in the way they cause minimal disruption to the river's flow, so that they can remain in place permanently. The continuous construction and upkeep of these traps over many centuries showcases the technological expertise of First Nations communities in this region (Figure 2.6.14).

KEY TERMS

intertidal zone the area of land on a coastline between high and low tides

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

estuarine a description of something related to an estuary where a river joins the sea

FIGURE 2.6.14 Brewarrina Fish Traps

SC 3 CHECK YOUR UNDERSTANDING

Describe how you would use tidal charts to plan a foraging trip along the coast.

Lesson review

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

1 What is tidal data?

2 Think about using tidal data to make predictions.
- **a** Why is it important to analyse tidal data?
- **b** How can patterns in tidal data help make predictions?
- **c** Explain the process of using tidal data to predict future tides.

3 Compare different uses of tidal information.
- **a** How is tidal information used differently in navigation and coastal management?
- **b** What are the benefits of using tidal information for navigation and coastal management?
- **c** What makes tidal information important in society?

4 Think about the role of tidal patterns in traditional practices of First Nations Australians.
- **a** Why are tidal patterns important for foraging activities?
- **b** How do tides affect the availability of marine resources?
- **c** Explain how understanding tidal patterns benefits First Nations Australians.

2.7 Phases of the Moon

Learning intention

To understand the phases of the Moon

Success criteria

SC 1: I can name and describe the appearance of the key phases of the Moon.

SC 2: I can explain what causes the phases of the Moon.

SC 3: I can predict the phase of the Moon for a given configuration of Earth, the Moon and the Sun.

KEY TERMS

lunar phase the appearance of the Moon from Earth as it changes over the course of a month

waxing the lunar phases after a new moon where the illuminated portion of the Moon is increasing

waning the lunar phases after a full moon where the illuminated portion of the Moon is decreasing

crescent moon a phase of the Moon where less than half is illuminated

gibbous moon a phase of the Moon where more than half is illuminated

Lesson overview

The Earth, Sun and Moon systems create different phenomena that are observable from Earth, including the changing appearance of the Moon throughout the month.

In this lesson you will learn about the different phases of the Moon and how they are produced.

SC 1	I can name and describe the appearance of the key phases of the Moon

Appearance of the Moon

Sometimes when looking at the Moon in the night sky, you can see the whole round face of the Moon. Other times, you might see a small slice of the Moon, or perhaps you will not be able to see the Moon at all.

The different shapes or views of the Moon from Earth are called **lunar phases**, or moon phases. The Moon does not emit its own light, but its surface is good at reflecting light from the Sun.

Waxing and waning

It is called **waxing** as more and more of the Moon is visible after a new moon. It is called **waning** as less and less of the Moon is visible after the full moon.

Crescent and gibbous

When less than half of the Moon is visible (or illuminated), it is called a **crescent moon**. When more than half of the Moon is visible it is called a **gibbous moon**.

Lunar phases

There are eight key phases of the Moon during the Moon's 27-day orbit around Earth. The Moon changes slightly each day as it gradually progresses through the cycle (Figure 2.7.1). Table 2.7.1 explains the eight phases of the Moon as observed from the Southern Hemisphere. (Note that the view from the Northern Hemisphere is upside down compared to the view from the Southern Hemisphere.)

TERMINOLOGY TIP

A first quarter moon refers to the Moon being a quarter of the way through its cycle, not how much of the moon is visible (or illuminated). A first quarter moon is sometimes called a 'half moon' because half of the moon is visible. A third quarter moon refers to the Moon being three-quarters of the way through its cycle. A third quarter moon will have the opposite half illuminated when compared to a first quarter moon.

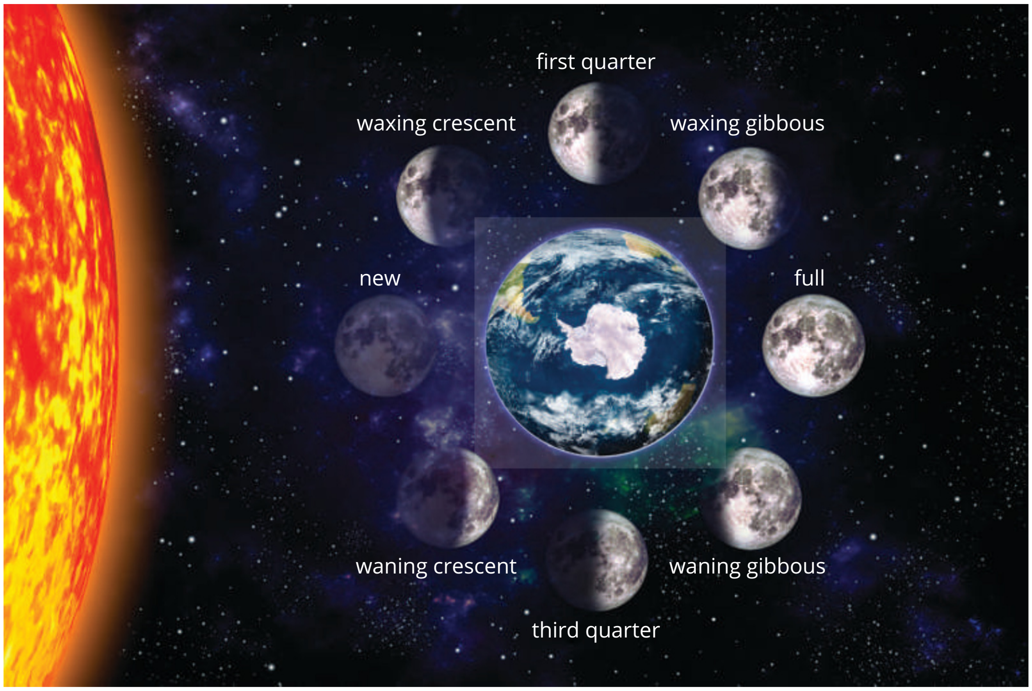


FIGURE 2.7.1 The phases of the Moon depend on the location of the Moon with respect to Earth and the Sun. This diagram shows the phases of the Moon as seen from the Southern Hemisphere.

TABLE 2.7.1 Eight Moon phases as observed from the Southern Hemisphere

New moon	The Moon is in the first phase in the lunar cycle, and in this phase the Moon is not visible. The side of the Moon facing Earth is not illuminated by the Sun at all.
Waxing crescent	Only a small, curved section, or crescent of the Moon is visible during this phase. Most of the side of the Moon facing Earth is not illuminated. The amount of the Moon that is illuminated increases each day during the waxing phases.
First quarter	The Moon is a quarter of the way through the cycle and half of the side of the Moon facing Earth is illuminated.
Waxing gibbous	During this phase, more than half of the side of the Moon facing Earth is illuminated. The visible section of the Moon continues to increase each day.
Full moon	The entire side of the Moon facing Earth is illuminated.
Waning gibbous	During this phase, more than half of the side of the Moon facing Earth is illuminated. The visible and lit section of the Moon decreases each day during waning phases.
Third quarter	The Moon is three quarters of the way through the lunar cycle and the half opposite to that of the first quarter is illuminated and visible from Earth. A third quarter moon is also known as a last quarter moon.
Waning crescent	The Moon has nearly completed the lunar cycle and only a small crescent opposite to that of the waxing crescent is visible. The amount of the Moon that is visible and illuminated continues to decrease each day. After this phase, the cycle reaches the new moon phase again.

SC 1 CHECK YOUR UNDERSTANDING

List the eight key phases of the Moon.

SC 2 I can explain what causes the phases of the Moon

What is visible from Earth?

The Moon does not have its own light source. Moonlight is the reflection of sunlight off the Moon's surface. Half of the Moon is always illuminated by the Sun. The half of the Moon that is illuminated is not always visible from Earth.

The view of the Moon from Earth changes as different portions of the Moon illuminated by the Sun are visible. The same side of the Moon always faces Earth but the amount of sunlight on the side of the Moon facing Earth changes. The amount of the Moon that is visible, or the phase of the Moon, depends on the relative positions of the Moon, Earth and the Sun (Figure 2.7.2).

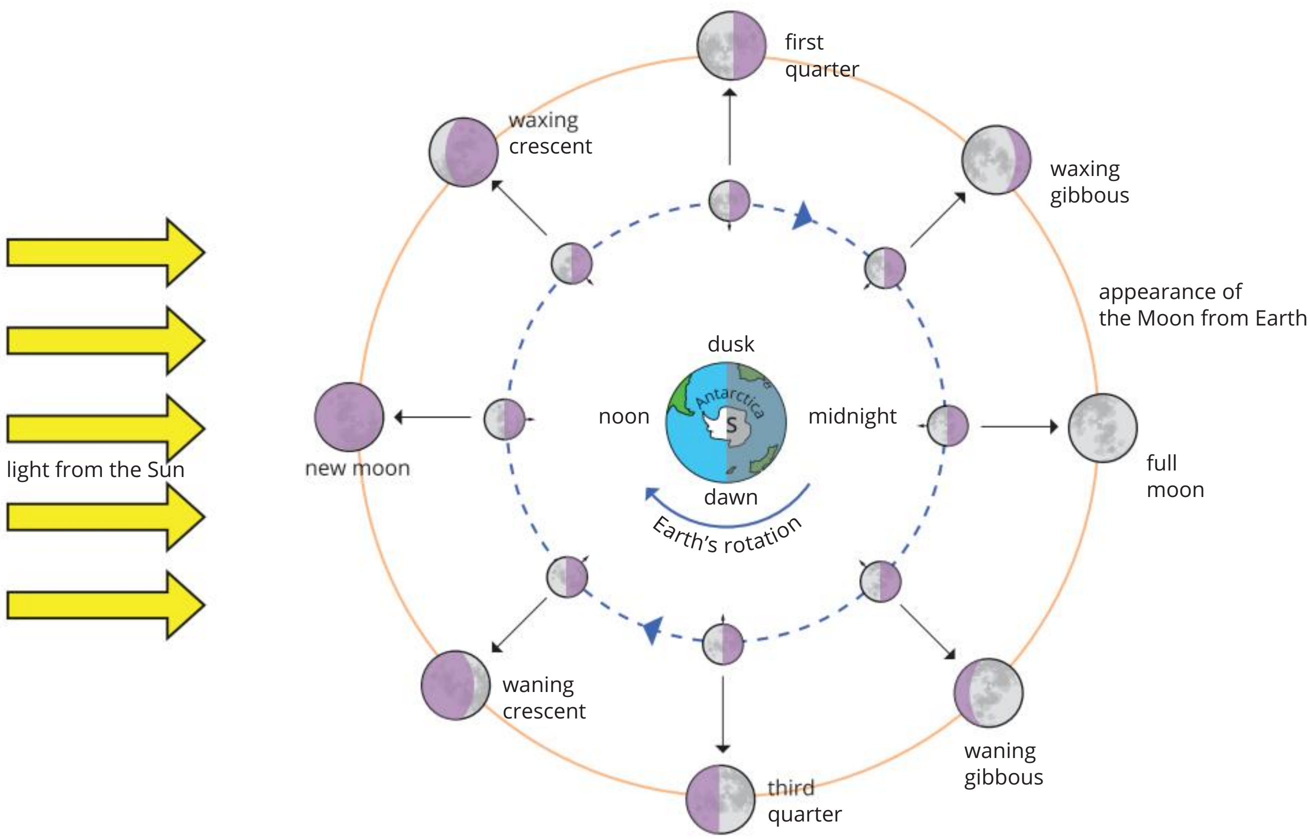


FIGURE 2.7.2 The view of the Moon changes as it orbits Earth, leading to different phases of the Moon being visible from Earth. The positions of the Moon are shown on its orbit and the outer diagrams show the Moon's appearance from Earth in the Southern Hemisphere.

The Moon orbits Earth as Earth orbits the Sun, so the alignment of the Moon, Earth and the Sun changes over time. To predict how the Moon looks from Earth, you need to imagine yourself standing on Earth where you can see the Moon at a specific location. For some phases, this is simple. For example, when you see a third quarter Moon you are somewhere between midnight and noon on the surface of Earth and the sunlit part of the Moon appears on your right. For other phases, it is much more complicated to understand. Try it for yourself and then check your prediction using Figure 2.7.2. Choose a time of day and along the Moon's orbit you can see when the Moon will be visible at this time.

Then, imagine standing on Earth looking at the Moon in that position. Does your prediction of what it looks like match the diagram around the outside showing how the Moon appears?

SC 2 CHECK YOUR UNDERSTANDING

Identify the cause of the Moon's phases.

SC 3 I can predict the phase of the Moon for a given configuration of Earth, the Moon and the Sun

A gradual change

The relative position of Earth, the Moon and the Sun determines the amount of light reflected by the Moon to Earth and the corresponding moon phase.

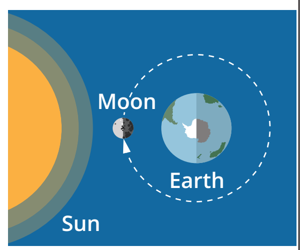
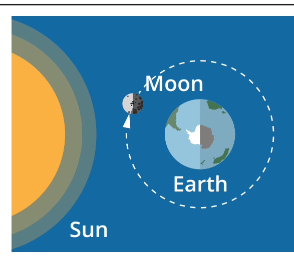
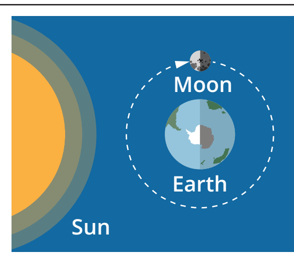
The phases of the Moon change gradually throughout the lunar cycle. As the Moon orbits Earth, it slowly moves into a new position in the sky and the Sun illuminates different parts of the Moon's surface.

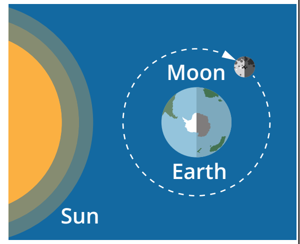
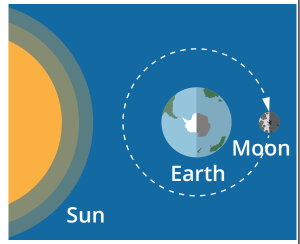
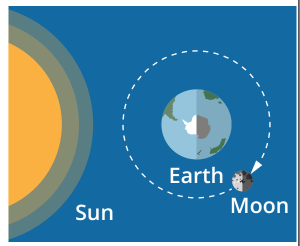
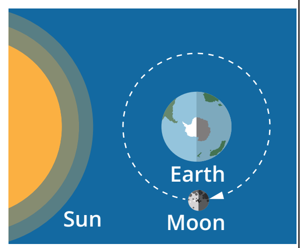
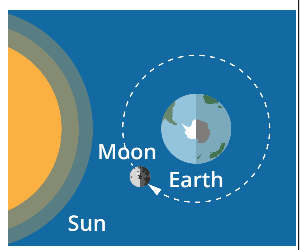
The images in Table 2.7.2 explain each of the phases of the Moon. Look carefully at the alignment of the Moon, Earth and Sun to predict what can be seen from Earth. The images on the right show the view of the Moon from Earth.

DISCOVER MORE

The Moon takes 27.3 days to orbit Earth. However, it takes 29.5 days for the Moon to cycle from a new moon to a full moon and back to a new moon again. This difference occurs because the orbit of the Moon around Earth is not aligned with the orbit of Earth around the Sun. This affects how the sunlight appears on the Moon when viewed from Earth.

TABLE 2.7.2 The positions of Earth, the Moon and the Sun and the appearance of the Moon from Earth

Moon phase	Alignment	What is visible from Earth	Arrangement of the Sun, Earth and the Moon	View of the Moon from Earth
New moon	The Moon is in the middle of the Sun and Earth. The Moon, the Sun and Earth are aligned.	Difficult to see; near the Sun in the sky; the side facing Earth is in shadow.		
Waxing crescent	The Moon moves out of alignment with the Sun and Earth.	A small and increasing portion of the Moon is illuminated.		
First quarter	The Sun, Earth and the Moon form a right angle. The Moon is one-quarter of the way through its orbit.	Half of the visible side of the Moon is illuminated.		

Waxing gibbous	The Moon moves towards alignment with the Sun and Earth.	More than half of the Moon is illuminated.		
Full moon	The Moon and the Sun are on opposite sides of Earth. The Moon, the Sun and Earth are aligned.	The visible side of the Moon is fully illuminated.		
Waning gibbous	The Moon moves out of alignment with the Sun and Earth.	More than half of the Moon is illuminated, but the lit portion is decreasing.		
Third quarter	The Sun, the Moon and Earth form a right angle.	Half of the Moon is illuminated.		
Waning crescent	The Moon is moving to realign with the Sun and Earth.	Less than half of the Moon is illuminated, and the lit portion is decreasing.		

SC 3 CHECK YOUR UNDERSTANDING

Predict the phase of the Moon if the Moon is at a 90° angle to the line between Earth and the Sun.

Lesson review

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

1 Consider the phases of the Moon.
- **a** What is the phase called when the Moon appears dark?
- **b** What phase comes after the full moon?
- **c** Describe the appearance of the first quarter moon.

2 Describe the positions of Earth, the Sun and the Moon in the full moon phase.

3 Explain how the positions of Earth, the Moon and the Sun create the new moon phase.

4 Explain how you can predict the Moon's phase based on its position relative to Earth and the Sun.

2.8 Modelling 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. Models are a useful way to visualise something that is difficult to see or understand, such as the changing positions of the Sun, Earth and the Moon in space.

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.

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.

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 experiment 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 the appearance of the Moon changes and why Moon phases occur

Materials and safety

Write a materials list and safety notes 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.

HINTS

- 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.

Method

1. Place your light source, or 'Sun', on a table or desk that you can stand near.
2. Turn on your 'Sun' (light source).
3. Darken the room by turning off all other lights and closing all curtains or blinds.
4. Face towards the 'Sun' and hold your 'Moon' out in front of you.
5. Record the amount of light you can see on the side of the 'Moon' that faces you in this position—position 1 in your results table. You can take a photo or complete a drawing.
6. Slowly start turning clockwise, to your right, and stop when you have turned one-eighth of the way around the circle.

HINT

Copy the results table into your notebook or construct a digital table in which you can add photos.

HINT

Remember your head is 'Earth'.

7 Record the amount of light you can see on the side of the 'Moon' facing you in this position.

8 Continue turning clockwise and stop every one-eighth of a turn to record the amount of light you can see on the side of the 'Moon' facing you in each position.

Results

Record your results in your copy of this table.

	Position							
	1	2	3	4	5	6	7	8
View of the 'Moon'								

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 1 and position 5?

2 What happened to the amount of light you could see on the 'Moon' after position 5?

3 How would you describe the relative position of 'Earth', the 'Moon' and the 'Sun' at position 5?

4 Compare the results of position 3 and position 7 and describe what you observed.

5 Figure 2.7.1 shows a 2D 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. Identify each phase for positions 1–8.

Evaluation

Evaluate your practical investigation by answering the following questions.

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.

3 Consider limitations of the model and any changes you could make to give a more accurate representation of the real system in space.

2.9 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

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 2.9.1 shows the two parts of Earth's shadow:

- The **penumbra**—the 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.

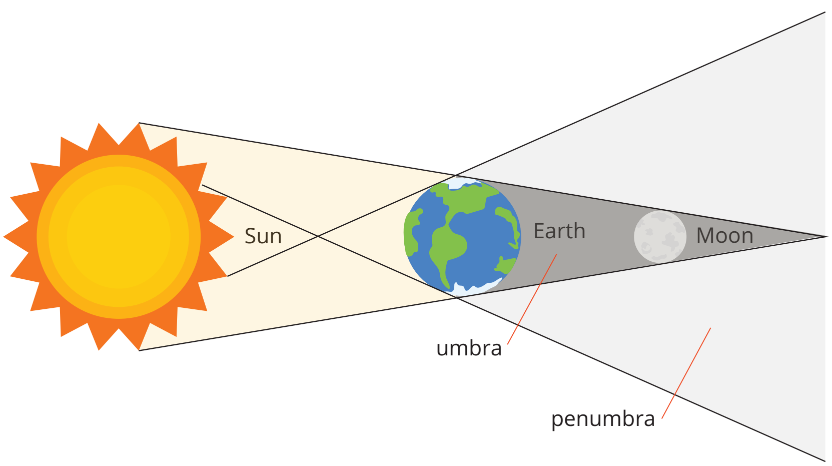


FIGURE 2.9.1 The arrangement of the Sun, Earth and the Moon during a lunar eclipse and the regions within Earth's shadow

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.

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.

KEY TERMS

penumbra the less dense shadow of an eclipse
umbra the full dark shadow of an eclipse

Scifile

Ancient explanations

Many ancient cultures had their own explanations for lunar eclipses. Some believed that a dragon or other creature was eating the Moon, while others thought it was a sign from the gods.

FIGURE 2.9.2 Part of the Moon is covered by Earth's umbra during a partial lunar eclipse.

FIGURE 2.9.3 The phases of a lunar eclipse

FIGURE 2.9.4 The orange colour of an eclipsed moon

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 2.9.2).

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

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 2.9.3 shows a time lapse photograph 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

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 2.9.4).

Viewing a lunar eclipse

A lunar eclipse can be seen by anyone on the night side of Earth as 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. A lunar eclipse can last up to two hours.

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 and the Sun and the Moon on opposite sides of Earth (Figure 2.9.5). This formation only occurs during the full moon phase. A full moon occurs every moon cycle, which is about once a month.

FIGURE 2.9.5 The Sun, Earth and the Moon are directly aligned during a full moon and a lunar eclipse.

Not every full moon

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 plane (an imaginary flat surface) of Earth's orbit. The tilt of the Moon's orbit is shown in Figure 2.9.6.

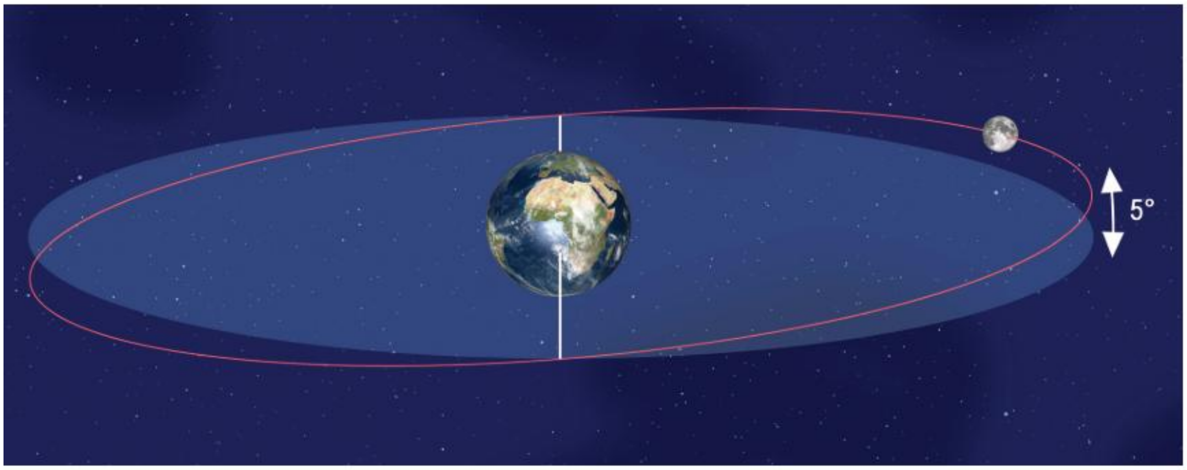


FIGURE 2.9.6 The Moon is only aligned with Earth's shadow occasionally due to the tilt of its orbit, so lunar eclipses do not happen often.

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 2.9.7 shows the relative positions of the Sun, Earth and the Moon during a lunar eclipse.

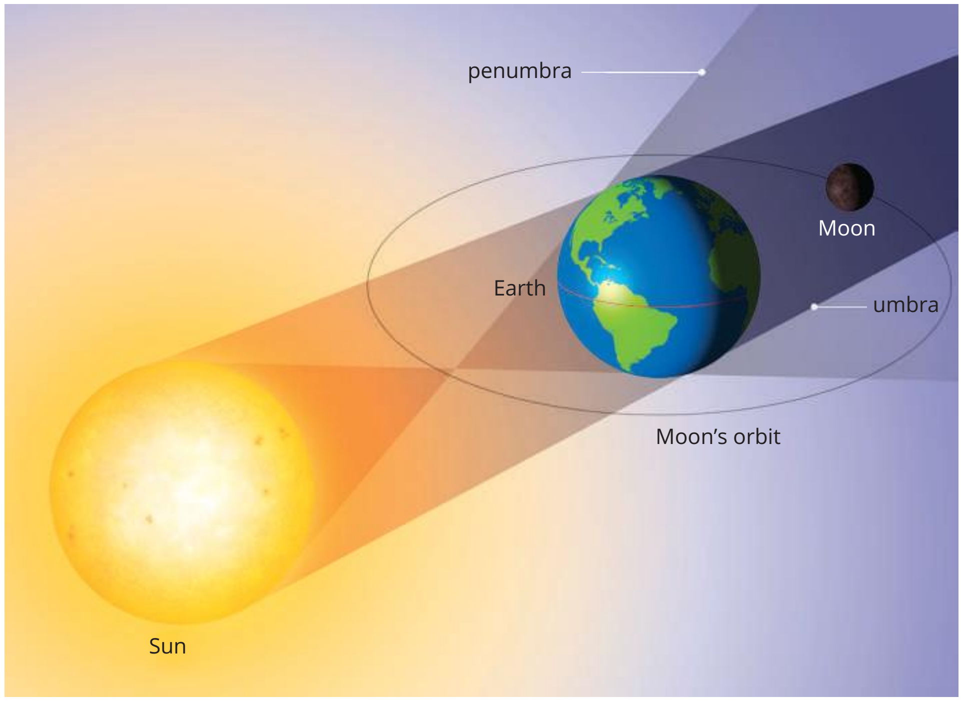


FIGURE 2.9.7 The relative positions of the Sun, Earth and the Moon during a lunar eclipse

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.

Lunar eclipses are 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 you to visualise 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 2.9.8, uses physical objects to represent Earth, the Sun and the Moon and can include physical movement.

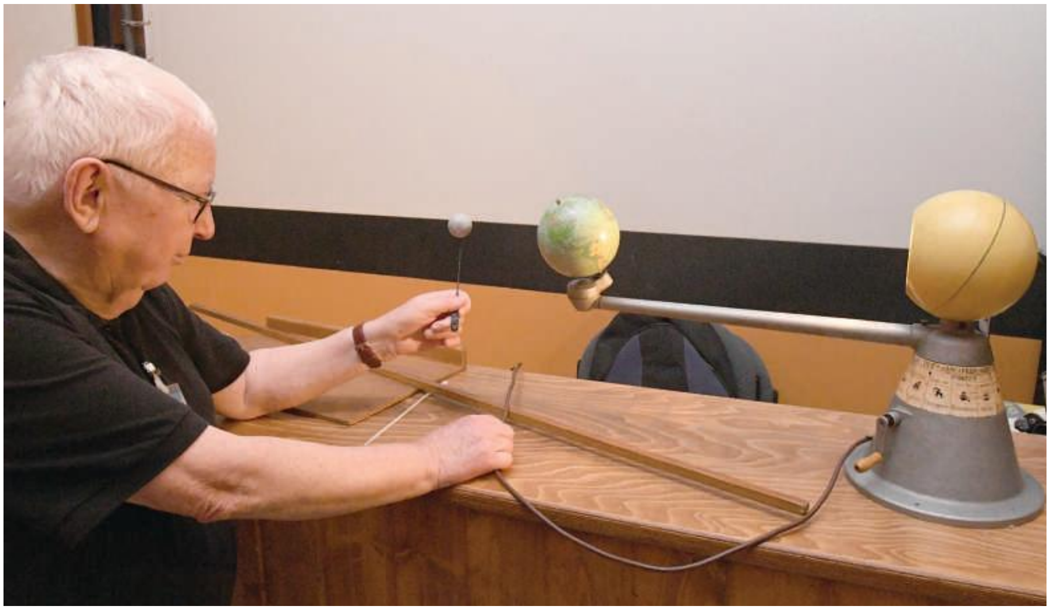


FIGURE 2.9.8 A 3D model of the Sun-Earth systems

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
- Earth is closer to the Moon 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 2.9.9.

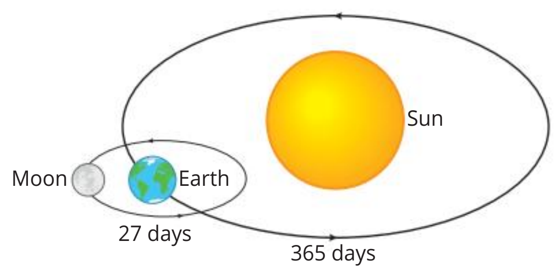


FIGURE 2.9.9 A 2D model of the Sun, Earth and Moon systems

Worked example

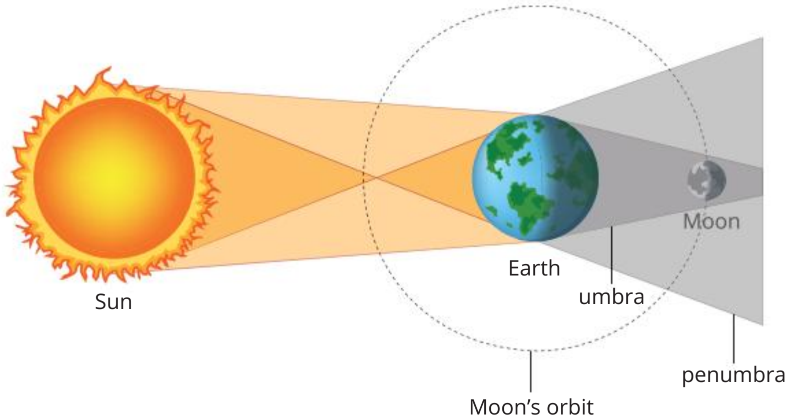
Using models in Earth and space science

Problem

Use the following information to make a 2D model of a lunar eclipse.

A lunar eclipse occurs when the Sun, Earth and the Moon are aligned, with the Sun and the Moon on opposite sides of Earth. As the Moon moves into Earth's shadow during its orbit, Earth blocks the direct sunlight from reaching the Moon. The Moon first travels through the lighter outer shadow (the penumbra), then through the darker inner shadow directly behind Earth (the umbra).

Solution

Thinking	Working
List the elements you need to represent with your model.	Sun Earth Moon sunlight shadow
Consider the placement of the Sun, Earth and the Moon in relation to each other.	The Sun, Earth and the Moon are aligned, with the Sun and the Moon on opposite sides of Earth.
Consider the relative sizes of, and distances between, the objects.	The Sun is bigger than Earth and Earth is bigger than the Moon. The distance between the Moon and Earth is smaller than the distance between Earth and the Sun.
Draw or make the model.	 To model a lunar eclipse, the Sun, Earth and the Moon must be arranged in this way.

Try yourself

Create an annotated sketch to plan how you would go about making a 3D model of a lunar eclipse.

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.

2.10 Cultural influence on knowledge about lunar eclipses

Learning intention

To be able to explore the influence of cultural perspectives on scientific knowledge about lunar eclipses

Success criteria

SC 1: I can describe the work and cultural context of acclaimed female scholar, Wang Zhenyi.

SC 2: I can explain how culture influenced the study of lunar eclipses.

SC 3: I can describe how Wang Zhenyi used experimentation to study lunar eclipses.

Introduction

Culture and context have an important influence on scientific research and discovery (Figure 2.10.1). The eighteenth-century Chinese scholar Wang Zhenyi was an important influence in the field of astronomy. Wang Zhenyi studied the movements of the Sun, the Moon and planets and described lunar eclipses.

In this inquiry, you will be able to explore how Wang Zhenyi's cultural perspectives influenced her knowledge about lunar eclipses.

FIGURE 2.10.1 Astronomers in China in the 18th century

Background

Wang Zhenyi was a Chinese scientist of the eighteenth century from the Qing dynasty (1636–1912). She was very influential for her time which was unusual for a female. Wang Zhenyi's involvement in science was not typical as women were expected to play a limited role in society at that time. Women could not own property and had to obey male members of their family. Opportunities for careers and education for women were restricted. It was culturally unusual for women to be interested in science and to have an education.

Despite the culture, Wang Zhenyi's family valued education and encouraged her to follow her interests in science and poetry. Wang Zhenyi was influenced by her grandfather, who was her teacher of astronomy, her grandmother, who taught her poetry, and her father, who taught her medicine, geography and mathematics. At the age of 18, Wang Zhenyi focused on teaching herself astronomy and wrote many articles, including 'The Explanation of a Lunar Eclipse'.

Aim

To explore Wang Zhenyi's cultural context (historical and social background in which she lived, including the values and beliefs of her society), and how these influenced her work on lunar eclipses

Plan

1. Investigate the cultural context surrounding Wang Zhenyi. Consider where her passion for astronomy originated. Where did she learn about the stars and planets? What were her contributions in the field of astronomy? What barriers did she face as a woman studying astronomy in the eighteenth century?
2. Describe or draw an image of how a lunar eclipse occurs.

Design

1. Research how Wang Zhenyi made a model to prove her theory about lunar eclipses.
2. Design a model that takes inspiration from Zhenyi's experiment.

Conduct

Using your design, create a model of a lunar eclipse, drawing inspiration from Wang Zhenyi's model.

Improve

Consider the model you have created.

1. What parts of your model worked well?
2. What parts of your model needed improvement?
3. How could you modify your model of a lunar eclipse to make it better?

Evaluate

1. What aspect of culture were you investigating in this inquiry activity?
2. In this activity, you planned and conducted an inquiry about lunar eclipses, drawing inspiration from Wang Zhenyi. What skills did you use during this activity?

2.11 Solar eclipses

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.

KEY TERM

solar eclipse when the Moon blocks sunlight from reaching Earth

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

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 2.11.1.

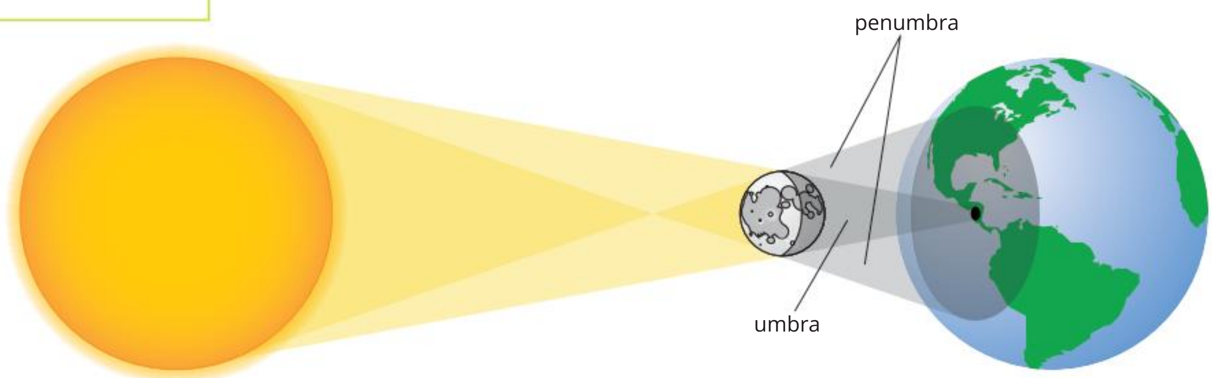


FIGURE 2.11.1 The shadow of the Moon on Earth has a darker area where all light from the Sun is blocked (umbra) and lighter areas where some of the light from the Sun is blocked (penumbra).

FIGURE 2.11.2 A partial eclipse during sunrise

Partial solar eclipse

During a partial solar eclipse, the Sun is only partly covered by the Moon (Figure 2.11.2). 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.

Total solar eclipse

During a total solar eclipse, the Sun is completely blocked by the Moon (Figure 2.11.3). The sky darkens and the Sun cannot be seen. Only the glow of the Sun's outer atmosphere 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 narrow dark shadow directly behind the Moon.

FIGURE 2.11.3 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

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 2.11.4). The Moon appears as a smaller disc over the top of the disc 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 to 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.

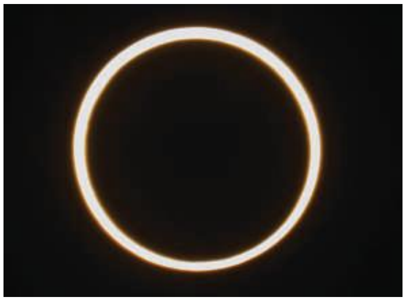


FIGURE 2.11.4 An annular eclipse

Viewing a solar eclipse

Solar eclipses can't be seen from all places on Earth. They are only visible from the part of Earth in the path of the Moon's shadow. Most solar eclipses are only viewed as partial eclipses because the penumbra falls on a larger area. Only a small area of Earth falls under the umbra. Only locations falling within the umbra will see a total solar eclipse. On average, there are two to five solar eclipses each year. Whether you can see the eclipse depends on where you are on Earth.

Solar eclipse safety

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 2.11.5), or a projection like a pinhole camera.

FIGURE 2.11.5 You can view the Sun safely using eclipse glasses.

SC 1 CHECK YOUR UNDERSTANDING

Identify the phase of the Moon during a solar eclipse.

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 2.11.6). This formation only occurs about once a month during the new moon phase. A new moon occurs every moon cycle.

FIGURE 2.11.6 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. Recall that the Moon's orbit is slightly tilted at about 5° to the plane of Earth's orbit (Figure 2.11.7) and that this tilt of the lunar orbit is also why lunar eclipses do not occur every full moon.

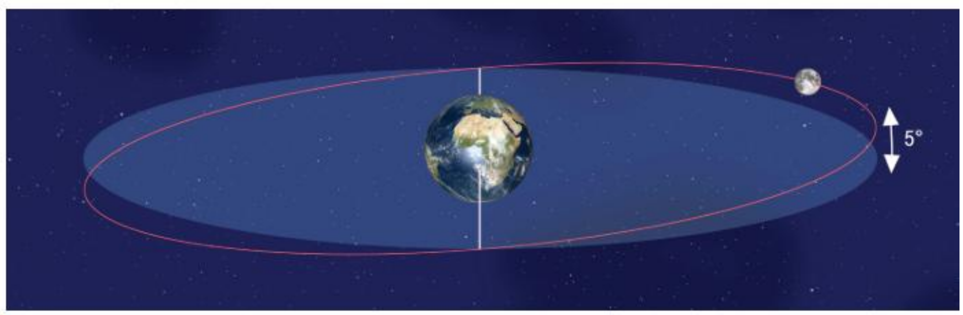


FIGURE 2.11.7 Solar eclipses do not happen often because of the tilt of the Moon's orbit.

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.

Geometry of a solar eclipse

When the Moon's orbit is in the same plane as Earth's orbit and the Sun, the Moon and Earth are aligned, the Moon casts a shadow on part of Earth's surface.

A partial eclipse is observable by someone on Earth if they are located within the penumbra shadow (Figure 2.11.8). 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.

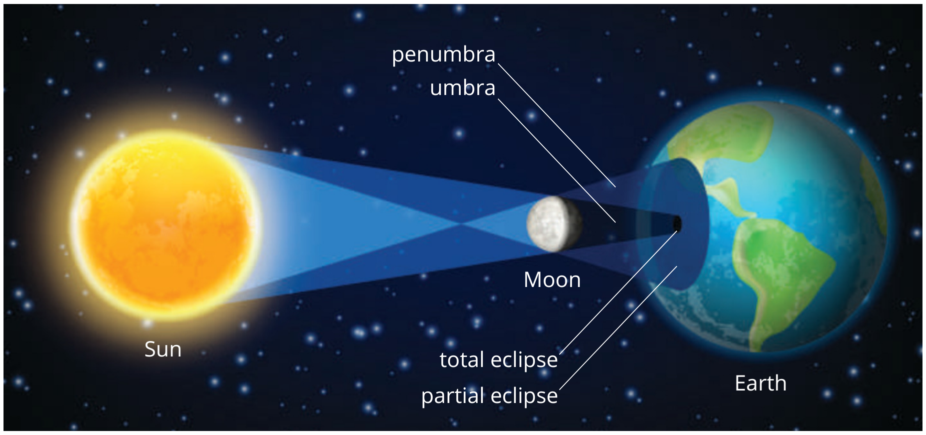


FIGURE 2.11.8 A view from space of the umbra and penumbra during a solar eclipse

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 2.11.9, the eye of the observer represents Earth. This model shows how the light from the Sun is blocked by the Moon.

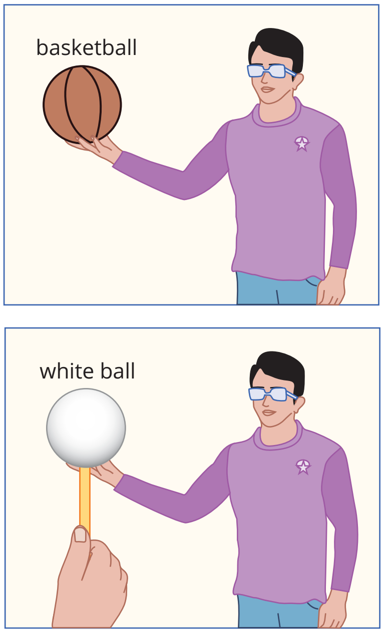


FIGURE 2.11.9 This model shows how the smaller white ball (representing the Moon) can block out all the light from the Sun (represented by the basketball) because it is relatively close to the observer on Earth.

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 than by a 3D model.

Lesson review

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

1 What does the Sun look like 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 3D 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?

Inquiry activity

2.12 Exploration of the Moon

Introduction

For as long as humans have gazed at the night sky, the Moon has been a focus of fascination. People have a long history of space exploration and research, specifically with the Moon.

In this inquiry, you will explore how Moon exploration over the last 50 years has been influenced by changing technology and economic and political factors.

Learning intention

To be able to explain how a range of factors have influenced the exploration of the Moon

Success criteria

SC 1: I can describe the historical factors that influenced the desire to send a person to the Moon.

SC 2: I can describe changes in space technologies since the Moon landings.

SC 3: I can compare the reasons for human presence on the Moon now to the time of the Apollo missions.

Background

The Space Race was a significant period in the history of space exploration, beginning in the late 1950s and continuing throughout the 1960s. During this time, the United States and the Soviet Union were in competition to be the first country to send a person to the Moon.

The Space Race led to several important achievements in space exploration, including the first human landing on the Moon in 1969.

Over the last 50 years, exploration of the Moon has changed significantly. Many technologies have been developed to support efficient and safe exploration in future landings. There are different ways that Moon exploration has been carried out by scientists and space agencies. The motivations for human presence on the Moon now, as compared to 50 years ago, are very different and there are many reasons for this.

SCIENCE IN SOCIETY

Lunar exploration

The exploration of the Moon has been significantly influenced by technological advancements. The development of rockets, spacecraft and navigation systems has made it possible to send missions to the Moon and beyond. The Apollo program, which successfully landed humans on the Moon in 1969, was made possible by innovations in engineering, computing and materials science. These technological advancements allowed astronauts to travel to the Moon, conduct scientific experiments and return safely to Earth.

The development of more powerful rockets, such as NASA's Space Launch System (SLS) and SpaceX's Starship, allows larger loads and more sophisticated instruments to be carried the Moon. Advances in robotics and artificial intelligence are enabling the design of autonomous rovers and landers that can explore the lunar surface and conduct scientific research without human intervention.

Australia is also contributing to lunar exploration through its involvement in international space missions and research (Figure 2.12.1). The Australian Space Agency collaborates with NASA and other space agencies to support lunar missions and develop new technologies for space exploration.

FIGURE 2.12.1 Australian-British astronaut Katherine Bennell-Pegg could be the first woman to walk on the Moon.

Aim

To create a presentation sharing the reasons for the human presence in space now as compared to the time of the Apollo missions

Plan

Explore the timeline of space exploration for the following Apollo missions.

Summarise the key reasons for human presence on the Moon in the days of the Apollo missions.

Apollo 8

In 1968, Apollo 8 circled the Moon for almost a day. This mission was the first time people were able to gaze at the Moon from orbit.

Apollo 8

Apollo 8 spacecraft and the Moon in December 1968

Apollo 10

In 1969, Apollo 10 orbited the Moon to test the Lunar Lander and the possibility of Moon landings. The lunar module was designed to transport astronauts from the command/service module in lunar orbit to the surface of the Moon and back. Many high-resolution photographs were taken detailing the Moon's surface, which increased knowledge of lunar geology.

Apollo 10

An in-flight photo of Apollo 10 astronauts Thomas Stafford and John Young in May 1969

Apollo 11

In July 1969, Apollo 11 landed on the Moon and astronauts walked on the Moon for over 2 hours. They took soil samples and learnt that the Moon had once been nearly completely molten—covered in a layer of liquid rock. The astronauts found no evidence of any significant amount of water on the Moon then or in the past.

Apollo 11

Apollo 11 astronaut Buzz Aldrin on the Moon on 21 July 1969

Apollo 12

In November 1969, Apollo 12 landed on the Moon. The astronauts collected over 35 kg of samples, which provided information about the ages of rocks and soil on the Moon's surface, especially those found in craters such as Copernicus. This information allowed scientists to create a timeline of the Moon's formation.

Apollo 12

Apollo 12 astronaut Alan Bean climbing down the ladder of the lunar module Intrepid for a spacewalk on the Moon's surface on 19 November 1969

Apollo 13

The Apollo 13 mission in April 1970 became a rescue mission when a panel of the service module ripped off after an in-flight explosion before the craft reached the Moon. All three astronauts returned safely after using problem-solving skills and the technology on the craft to use the limited fuel and oxygen in the lunar module to power them back home to Earth.

Apollo 13

The damaged Apollo 13 service module in April 1970

Apollo 14

On 5 February 1971, Apollo 14 astronauts collected over 43 kg of rocks and soil. These samples informed scientists that the Moon's crust formed over 4.4 billion years ago and confirmed that lava (semi-molten rock) flows had once covered large areas of the Moon's surface.

Apollo 14

A NASA astronaut exploring the surface of the Moon as photographed by an Apollo 14 crew member in February 1971

Apollo 15

On this mission, over 80 kg of samples were collected and 20% of the Moon's surface was mapped from orbit. Apollo 15 was the first mission to use a lunar roving vehicle, which allowed travel farther from the landing site and exploration of larger areas. It also enabled more samples to be collected so that more experiments could be carried out than previous missions.

Apollo 15

Apollo 15 astronauts deploying the first lunar roving vehicle on the surface of the Moon on 31 July 1971

Apollo 16

On this mission, the first astronomical telescope was deployed and operated on the Moon. Ancient crustal rocks were found, as well as a very strong magnetic field on the surface the Moon, which was then measured.

Apollo 16

Astronaut Charles M. Duke Jr. collecting lunar samples during the Apollo 16 mission in April 1972

Apollo 17

Apollo 17 landed on the Moon on 11 December 1972. The Apollo 17 mission made several significant discoveries on the Moon. Astronauts collected a variety of rock samples and conducted several experiments to study the geological history and composition of the Taurus-Littrow Valley. New rock samples and data helped to refine estimates of the Moon's formation and early history. Orange soil was later determined to be rich in volcanic glass and other minerals. This discovery helped scientists better understand the Moon's geology and volcanic history.

Overall, the Apollo 17 mission was a significant milestone and helped expand knowledge of the Moon's geology, history and its potential as a resource for future exploration.

Apollo 17

Eugene Cernan on the Moon during the Apollo 17 mission

Scifile

Human presence on the Moon

Today, space agencies such as NASA and private companies are planning new missions to the Moon. These missions aim to establish a sustainable human presence and use the Moon as a stepping stone for further space exploration.

GO TO
Toolkit sections 4.2, Referencing secondary data and 4.3, Selecting and using secondary data

Design

1 Research at least two changes to space technologies related to the exploration of the Moon since the moon landings and record your key findings.

2 Research a current scientific reason for human presence on the Moon.

3 You will be creating a presentation that compares the key reasons for human presence in space now to the time of the Apollo missions. Design a way to present your findings. Map out key headings as well as the format of your presentation.

Conduct

Use your notes from the plan and design sections to create a presentation outlining the key reasons for human presence in space now compared to the times of the Apollo missions. The format of the presentation will be decided by your teacher.

Improve

Write down how you can improve your presentation by considering how well you were able to communicate your key findings to the audience.

Evaluate

Evaluate your work during this activity by describing the knowledge and skills that you gained or improved by completing the task.

2 Systems in space: The Earth, Sun and Moon

Topic summary

The key concepts included in this topic are:

- The Moon orbits Earth, and both Earth and the Moon orbit the Sun.
- Earth's axis is tilted. This means, as it orbits the Sun, one hemisphere is tilted towards the Sun, then 6 months later the other hemisphere is tilted towards the Sun. The hemisphere tilted towards the Sun receives more direct sunlight and experiences summer.
- First Nations Australians developed seasonal calendars to predict the seasonal availability of food and seasonal conditions.
- The gravitational pull of the Moon and Sun on Earth's oceans causes tides.
- Society uses an understanding of the tides to plan activities in coastal regions, such as recreation, construction, transportation and energy generation.
- The orbit of the Moon around Earth changes how much of the illuminated surface of the Moon you can see and therefore the shape the Moon is from your location. These 'shapes' are called the phases of the Moon.
- 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 shadow of the Moon falls on Earth and from Earth some or all of the Sun is blocked out (eclipsed).
- The exploration of the Moon has been influenced by competition between nations and a desire to explore or understand.

Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

Remember

1 Identify what causes different parts of Earth to experience different seasons.

2 Describe what a seasonal calendar is, as used by First Nations Australians.

3 What is the relationship between the Moon's rotation on its axis and its orbit around Earth?

4 Write the name of the key phase of the Moon when the
  a Moon appears round
  b Moon cannot be seen from Earth.

Understand

5 Explain the relative positions of Earth, the Sun and the Moon in the solar system.

6 Explain how the intensity of sunlight is responsible for a location on Earth experiencing summer and then winter 6 months later.

7 Phoebe was given a desk lamp, a thermometer and a protractor.
Explain how Phoebe could use this equipment on a flat surface to model the changing angles of sunlight that fall on Earth in different seasons.

8 Plan how to you could use a model to demonstrate the phases of the Moon.

9 Explain why Earth, the Moon and the Sun need to be in particular positions for a lunar eclipse to occur.

Apply

10 Describe how Earth's seasons would change if the North Pole of Earth directly faced the Sun in January, and then in July, Earth's South Pole directly faced the Sun.

11 Outline how you could use a seasonal calendar to plan agricultural activities.

12 Compare the reasons for human presence on the Moon now to the time of the Apollo missions.

Analyse

13 Compare the gravitational pull of the Moon on Earth to the gravitational pull of Earth on the Moon.

14 Compare neap tides and spring tides in terms of their causes and effects.

15 Kylie made a model to demonstrate an eclipse. Her model is shown below. Explain which type of eclipse this model would represent.

Extension: Research

16 Research and describe how the phases of the Moon affect nocturnal animal behaviour.

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

astrophysicist a scientist who studies the behaviour and physical properties of objects and events in space

constellation a group of stars that form a recognisable pattern in the night sky

Country a term used by First Nations peoples to describe the lands, waterways, seas and skies they have a cultural connection to. The term contains complex ideas about identity, family, language, spiritual belief and law.

commerce buying and selling goods or services

Creation stories stories that explain the origins of the universe, the rules for living and the relationship of people to each other

crescent moon a phase of the Moon where less than half is illuminated

Earth's axis the line connecting the North Pole with the South Pole; Earth rotates around this axis

ecological a description of something that relates to ecosystems or interactions between living things and their environment

ecology the study of how organisms interact with each other and with their non-living surroundings

economy a system in which goods and services are produced and sold

ecosystem a system formed by organisms interacting with each other and their non-living surroundings

equator an imaginary horizontal line that divides Earth into the northern and southern hemispheres; it lies equal distance between the north and South Poles

estuarine a description of something related to an estuary where a river joins the sea

forage to search for something (usually food) over a wide area

full moon the phase of the Moon when the whole of the Moon seen from Earth is illuminated by the Sun

gibbous moon a phase of the Moon where more than half is illuminated

gravitational force the force on an object caused by gravity; can be described as the 'weight' of an object

gravity the force of attraction between any two objects

intertidal zone the area of land on a coastline between high and low tides

lunar related to the Moon

lunar cycle the period of 27.3 days that it takes for the Moon to orbit Earth

lunar phase the appearance of the Moon from Earth as it changes over the course of a month

magnitude a measure of the size or strength of something

mass the amount of matter in a substance or an object; measured in grams (g), kilograms (kg) or tonnes (t)

Moon a natural satellite that orbits Earth

new moon the phase of the Moon when 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

orbit curved path of a planet around a star, or of a moon or artificial satellite around a planet; orbits can be circular or elliptical

organism a living thing

planet a roughly spherical ball of rock or gas that orbit (moves around) the Sun; planets do not generate their own light

penumbra the less dense shadow of an eclipse

renewable energy source a source of energy that can be replaced after it is used, such as solar and wind energy

rotation the spinning motion of an object around a central line, called an axis of rotation

satellite a body in orbit around another body

science communicator a person who informs others who are normally non-experts about scientific findings, often with the aim of raising public interest in science

season 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, emitting light, heat and energy that reach Earth and other planets

topography the hills, valleys, rivers and other physical features of the landscape

tide the rise and fall of water levels in large bodies of water such as oceans and lakes, caused by the gravitational pull of the Moon on Earth

umbra the full, dark shadow of an eclipse

waning the lunar phases after a full moon where the illuminated portion of the Moon is decreasing

waxing the lunar phases after a new moon where the illuminated portion of the Moon is increasing

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

Particle theory and properties of substances

The world around you 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 them 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, their movement driven by forces such as gravity.

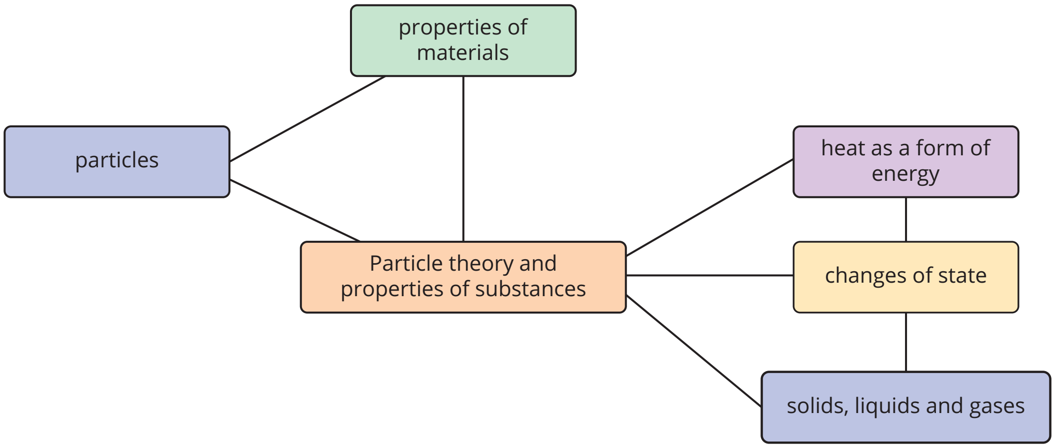
All this stuff, or matter, is made up of particles. You feel these particles when the wind blows, and they are what can either hurt or comfort you.

In this topic, you will learn about particles and how to explain and predict the properties of matter—the stuff around you.

Learning intentions

3 Particle theory and properties of substances

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 As part of a game, a student described the properties of a substance, and their friend had to guess what the substance could be.
The properties he described were that the substance was made up of crystals, was white, slightly shiny, hard and it dissolved when it was placed in water.
Suggest what you think the substance was.

Heat as a form of energy

2 Describe how the amount of heat energy can be measured in a science laboratory.

3 Explain why a metal object makes your skin feel cold when you touch it.

Solids, liquids, and gases

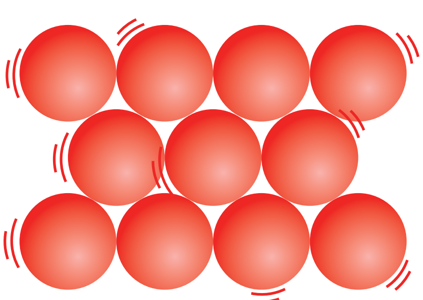
4 Name the following.
- **a** Three liquids that you might find in a bathroom
- **b** Three gases that are in the air
- **c** Three solids that are hard

5 Describe one thing that liquids and solids have in common.

Changes of state

6 Explain the difference between melting and evaporating and state one thing that these processes have in common.

Particles



7 The diagram to the left 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.

3.1 Three states of matter

Lesson overview

You can group your daily experiences into 'things you can't touch or see', like your thoughts and feelings, and 'things you can touch or see', like your school desk or trees. The things you can touch and see are called 'matter' (Figure 3.1.1). 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. All the stuff around you is made of matter, and so are you.

In this lesson you will learn what matter is, and how it is observed in the forms of solids, liquids or gases.

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.

SC 1 I can describe what matter is

Matter

Matter is any substance that has volume (meaning it takes up space) and mass (meaning it can be weighed). You and almost everything around you are matter, including things that are too small to see.

FIGURE 3.1.1 Matter can be a solid, a liquid or a gas, and includes living and non-living things.

Solids, liquids and gases

There are three forms (or **states**) 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 3.1.1.

TABLE 3.1.1 Examples of solids, liquids and gases

Solids	Liquids	Gases
Gym weights are solid and 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.
		

Explaining the three states of matter

The 'stuff' around you can normally be classified as a solid, liquid or gas. All these states of matter have 'mass'.

If gravity is present—as it is on Earth—mass is the **property** that causes things to have weight. If an object is taken into space and there is no gravity acting on it, it will still have mass, even though it is 'weightless'.

It might appear that gases do not weigh anything, but all matter, including gases has 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 in the balloon with a gas.

KEY TERMS

state solid, liquid or 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
property an observable characteristic of a substance; what a substance looks like and how it behaves

KEY TERMS

substance material that has physical properties; a solid, liquid or gas

gaseous in the form of a gas

pure substance a substance made of only one type of material

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

compressed reduced in volume (amount of space) or size by adding pressure

When people talk about matter, they often use the word **substance** to describe the thing that has mass. So, you can have solid substances like steel, liquid substances like mercury (the only liquid metal), or **gaseous** substances such as helium.

SC 1 CHECK YOUR UNDERSTANDING

Explain why air is considered to be an example of matter.

SC 2 I can classify different examples of matter as solid, liquid or gas

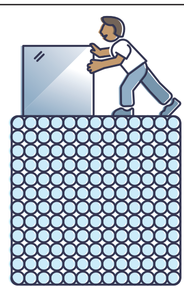
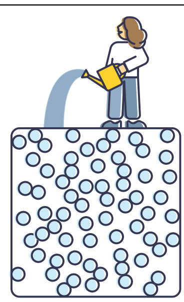
There are some rules that you can follow when looking at a **pure substance** to work out if it is solid, liquid or gas. These rules allow you to compare the properties (the appearance and behaviours) of substances and classify them as solid, liquid or gas.

Remember, many things are mixtures and do not follow these rules because they contain more than one solid, liquid or gas.

Identifying solids, liquids and gases

The key properties of solids, liquids and gases are shown in Table 3.1.2. These can be used to identify the state of a substance.

TABLE 3.1.2 Properties of solids, liquids and gases

Solids		• have a fixed shape (unless a force is applied to the solid) • have a fixed size and **volume** • cannot be **compressed**	
Liquids		• do not have a fixed shape—the liquid takes the shape of the container it is in • have a fixed volume • cannot be compressed • can flow	
Gases		• do not have a fixed shape—the gas spreads out in all directions to fill the container it is in • have no fixed size or volume • can be compressed • are often invisible (although some gases are coloured, such as yellow-green chlorine gas	

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 3.1.3). You do not see plasma very often, so this topic will focus on solids, liquids and gases.

FIGURE 3.1.3 The Aurora Australis (southern lights) are a form of plasma.

Is everything a solid, liquid or gas?

Think about all the things that you might use, eat and drink every day. Some of these things might be 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 might be more difficult to identify the state of matter they are because they are **mixtures** of more than one substance.

Mixtures

Some substances can be a mixture of solids, liquids and gases. For example, meringue is air (gas) trapped inside a cooked mixture of egg white (liquid) and sugar (solid). Shaving gel (Figure 3.1.4) contains water and a combination of oils and other chemicals.

When is a solid not a solid?

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 and then will be a solid again when it cools. This is how chocolate is set in different shapes, such as a heart (Figure 3.1.5).

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 and at parties.

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

FIGURE 3.1.4 Shaving gel is a mixture.

FIGURE 3.1.5 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.

FIGURE 3.1.6 Wet sand can behave as a solid or liquid.

Mixtures that can be solid or liquid

Mixtures, such as slime, Oobleck and wet sand (Figure 3.1.6) can also display the properties of solids and liquids. When you run on wet sand, it becomes more solid. However, when you walk, it behaves more like a liquid.

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 Ice, water and oxygen are all examples of matter.
   a Explain why each of these examples qualify as matter.
   b Describe the differences between the properties of ice, water and oxygen.

3 There is a fourth state of matter that can exist.
   a Name this fourth state of matter.
   b Explain why this fourth state of matter is rarely found in nature.

4 Explain why a reference temperature needs to be used when classifying substances as solids, liquids and gases.

5 A student was wanting to decide whether a type of yoghurt should be classified as a liquid or a solid.

Yoghurt – a solid or a liquid?

   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.

3.2 Matter and mass

Introduction

Mass is a way of measuring the amount of something. You use the units of grams and kilograms to measure mass (Figure 3.2.1).

Even where there is no gravity, such as in outer space, an object will be weightless, but 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.

FIGURE 3.2.1 Five kilograms is equal to 5000 grams.

Background

The mass of substances is measured in grams (g) or kilograms (kg): 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 0.1 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.

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

GO TO

Toolkit section 2.3, Using units in science

SAFETY NOTE

- Handle needles with care.

Method: Part A

How does the mass of liquids and solids change?

1 Place one ice cube in one 100 mL beaker and use the plastic cling wrap to completely seal the top of it.
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: Part A

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)
At start of the investigation		
After 20 minutes		
Change in mass		

Conclusion: Part A

Write a conclusion for Part A of your investigation by answering the following questions in your notebook.

1 Which beaker lost the most 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

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 0–1 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. 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, which 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 or get trapped inside the mechanism of the balance.

Procedure

Make sure the balance is placed on a flat surface away from other equipment and chemicals.

Make sure the pan of the balance is clean and dry.

Turn on the balance and use the re-zero (or tare) function to set the balance to 0.0 g.

Have your method of recording the measurement, such as a results table or spreadsheet, ready.

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.

Remove the object from the balance, turn it off and ensure that the balance is clean and dry for the next person.

Measuring the mass of copper sulfate crystals using an electronic balance

GO TO
Toolkit section 2.4, Taking measurements in science

HINT

Try to inflate the balloons to the same size at the start.

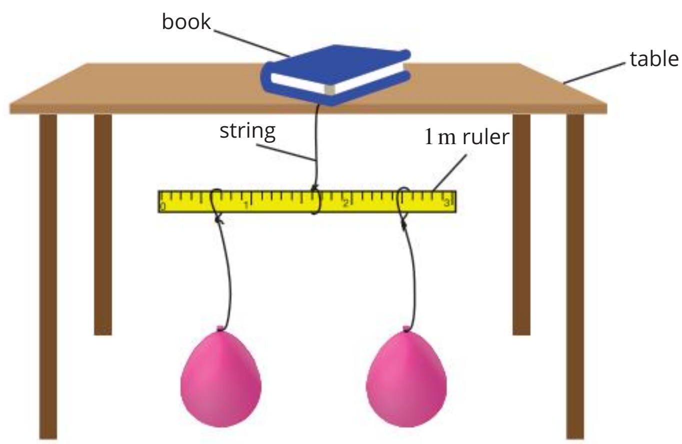
HINT

This experiment is a bit tricky but be patient when trying to balance the balloons.

Method: Part B

Do gases have mass?

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.
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.



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).

GO TO
Toolkit section 3.1, Types of scientific data

Results: Part B

In your notebook, record what you observed after the balloon was punctured.

Conclusion: Part B

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?

3.3 Matter and particles

Lesson overview

Matter is all the stuff around us, such as liquid water, solid metals and the gases in the atmosphere. Matter can also be described as materials or substances.

All matter is made of particles so small that you cannot see them without the use of an electron microscope such as the one used to produce the image in Figure 3.3.1. 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 all matter is made from particles, and how those particles are arranged to form solids, liquids and gases.

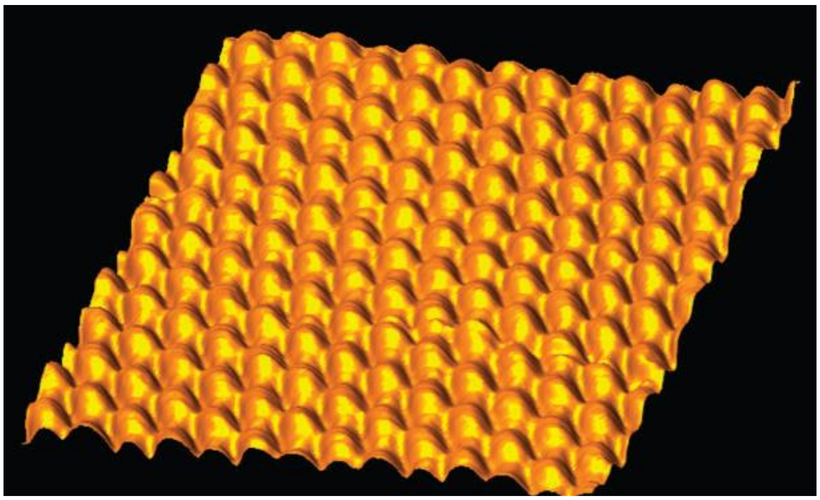


FIGURE 3.3.1 An image of particles (copper atoms) on the surface of copper metal created using a scanning tunnelling microscope

Learning intention

To understand how to construct and use diagrams that model the arrangement of particles in solids, liquids and gases

Success criteria

SC 1: I can draw and label two-dimensional representations of the arrangement and behaviour of particles in solids, liquids and gases.

SC 2: I can design and discuss suitable analogies for the representation of particles in solids, liquids and gases.

SC 3: I can explain the different properties of solids, liquids and gases using particle theory.

SC 1 I can draw and label two-dimensional representations of the arrangement and behaviour of particles in solids, liquids and gases

Representing particles that you cannot see

All matter, whether it is a solid, liquid or a gas, is made up of **particles**.

This can be explained using particle theory which states that that all matter consists of tiny particles that are constantly moving.

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 such as those shown in the images on the next page.

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. A model is considered 'scientific' if it is backed up with evidence from experiments and observations.

KEY TERMS

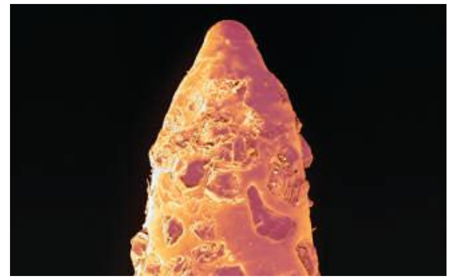
particle a tiny part of matter; includes atoms and molecules
particle theory the theory that states that all matter consists of tiny particles that are constantly moving
model a representation that helps to describe or explain an object, event, system or idea

Particle theory helps you answer questions such as the following.

Why does chocolate melt so easily?

Chocolate fountain

Why is a diamond so hard?



Diamond fragments on the tip of a drill

Why is mercury a liquid when all other metals are solids?

Droplets of mercury on a steel surface

Why does ice float on water?

Icebergs in the Arctic Ocean

Particle theory

Particle theory is based on the idea that all substances (matter) are made up of particles that are too small to be seen, even using microscopes.

Particles are:

- always moving (they have energy); the higher the temperature, the faster they move (because they have more energy)
- attracted to other particles, and 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).

Properties of matter

All properties of matter are linked to the behaviour of the particles that make up matter. The most important properties of matter are:

- whether it is solid, liquid or gas at room temperature
- its hardness
- its strength
- how well it mixes with other substances.

Scifile

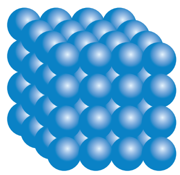
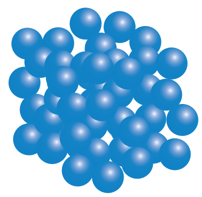
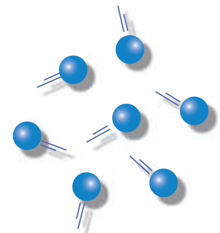
Crystals and patterns

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.

Particle behaviour in solids, liquids and gases

The different way 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 3.3.1.

TABLE 3.3.1 The structure and properties of the solids, liquids and gases

	Solid	Liquid	Gas
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 particles.
How the structure links to its 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 (**diffuse**) in all directions because of the high energy (speed) of particles and weak attractions between 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 of these collisions.

The pressure will also increase if the particles are moving faster because the collisions will have more force.

KEY TERMS

diffuse spread out

pressure the physical force exerted on an object or surface, measured as force per unit area

Reducing the volume of the container will also increase the pressure because there will be more collisions (Figure 3.3.2).

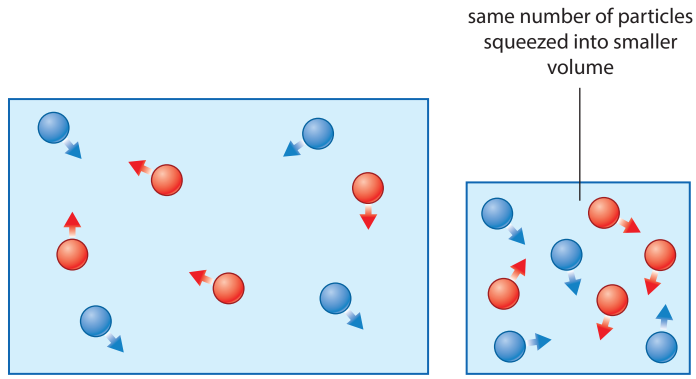


FIGURE 3.3.2 The effect of reducing the volume of a gas

SC 1 CHECK YOUR UNDERSTANDING

Explain, using a labelled diagram, how the particle arrangement in a liquid differs from that in a solid.

SC 2 I can design and discuss suitable analogies for the representation of particles in solids, liquids and gases

KEY TERM

analogy an event or situation that can be used to help describe or explain another similar event or situation

Analogies can help you to understand and explain scientific ideas.

An **analogy** is a model that uses something well known to help explain or describe something less familiar or more complex. For example, the bark on a tree could be used as an analogy for human skin.

Analogies can be very helpful when scientific ideas are abstract (cannot be experienced through your own senses)—but only if the analogy is a good one!

What makes a good analogy?

The best analogies are ones that:

- are designed by you, for you—all brains are different, so something that is good for one person might not be right for everyone
- have a lot in common with the real situation—this means you can explain the real situation using the analogy
- do not oversimplify the situation too much—this will only lead to a low-level understanding of the real situation
- are easy to understand, represent or imagine—you do not want to waste time trying to work out how the analogy works
- can be expanded to solve problems that you might come across later—this may be hard to judge at first, but being able to use your analogies again in the future is very helpful
- are fun and easy to remember—this makes the learning more enjoyable and you will use them more.

What is a good analogy for particle theory?

An analogy for particle theory should have a lot in common with the real situation, so it will need to represent:

- something that is made of lots of small things (the particles)
- particles moving (they can get faster and slower)
- particles that are attracted to other particles
- particles that can form different arrangements.

Evaluating analogies

Figures 3.3.3 and 3.3.4 show two possible analogies for the behaviour of particles. For each one, use the criteria above to rate how these analogies would help you explain particle theory.

Pool table

FIGURE 3.3.3 Would balls on a pool table be a good analogy for particle theory?

Rugby players

FIGURE 3.3.4 Could you use rugby players to model solids, liquids and gases?

SC 2 CHECK YOUR UNDERSTANDING

Explain why a group of marbles in a box is a good analogy for the particles in a liquid.

SC 3 I can explain the different properties of solids, liquids and gases using particle theory

A good theory, backed up with a good understanding and analogies, enables you to explain properties and events that you observe. Importantly, it also allows you to predict what things will do—how they will behave and how they might change.

There is a range of ways that you can use science understanding, such as the particle theory, to explain observations.

One of these is called the Premise, Reasoning, Outcome (PRO) thinking strategy. It works by describing the key knowledge (the premise), applying it to a situation (the reasoning), and stating the result (the outcome).

Worked example

Explaining properties using the Premise, Reasoning, Outcome thinking strategy

Problem

What will happen to the shape of an ice cream on a hot day?

Solution

This solution uses the PRO thinking strategy:

- Premise (the key science knowledge)
- Reasoning (applying the key science knowledge to the situation)
- Outcome (what is observed)

Thinking	Working
Premise: What key science knowledge is relevant to this question?	Particle theory—in a solid, particles are in fixed positions, and in a liquid, the particles are more free to move.
Reasoning: How can you apply the key science knowledge to the situation?	On a hot day, the particles in the ice cream behave more like a liquid because the attractions between the particles become weaker at higher temperatures.
Outcome: What is observed?	On a hot day, the ice cream turns into a liquid and no longer has a fixed shape.

Try yourself

Explain why a liquid has a fixed volume and a gas does not.

SC 3 CHECK YOUR UNDERSTANDING

Use particle theory to describe why gases can be compressed.

Lesson review

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

1. Describe the meaning of the term '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. Design an analogy to represent the particles in a gas and explain it.
5. Explain how the strength of attractions between particles affects the behaviour of solids, liquids and gases.

3.4 Matter under pressure

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 in Figure 3.4.1 from being compressed any more.

FIGURE 3.4.1 Particles of gas cause pressure inside the balloon.

Pressure surrounds you all the time. Just like other forces, 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.

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.

Background

A **theory**, such as particle theory, is an explanation of a set of observations. In this investigation you will use observations from the effect of pressure on liquids and gases to improve your understanding of particle theory.

KEY TERM

theory an explanation of a set of observations that has been accepted through consensus by a group of scientists

Aim

To investigate the behaviour of liquids and gases when they are compressed

Materials

- 250 mL beaker
- water
- plastic syringe (10 mL) (without needle)

SAFETY NOTE

- Excessive force may cause the water to explode out of the syringe and make a mess. Use only reasonable force.

GO TO
Toolkit section 1.3, Hypotheses and predictions

KEY TERM

prediction a statement that suggests what will happen in an experiment, normally based on a hypothesis

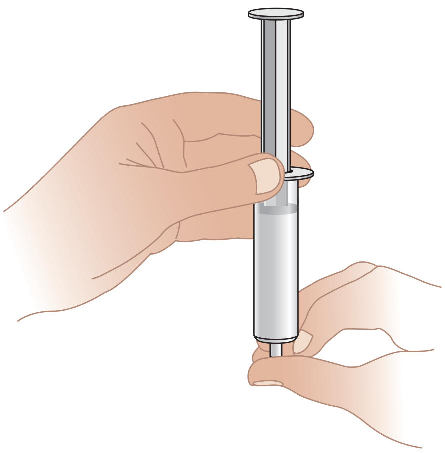


FIGURE 3.4.2 Trap the water in the syringe using your thumb.

HINT

Make sure that you keep your thumb tightly pressed against the end of the syringe to prevent leakage.

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 3.4.2.
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.

Results

1 Construct a results table like the one below in your notebook to record your observations. Remember to include a title for 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 by explaining how your observations provide evidence for the particle model of liquids and gases.

3.5 Heat and particles

Lesson overview

Energy is always present, and it affects what you do and how you feel (Figure 3.5.1). Even when you feel cold, energy is still there—there is just less thermal energy (heat) than when you feel hot.

All materials are made of particles, and thermal energy influences their movement. The more energy a material receives through heating, the more its particles move. When a material is cooled, its particles move less. These changes in energy can be measured by tracking temperature.

In this lesson, you will learn how particles—and the substances they form—behave when energy is transferred through heating or cooling.

SC 1 I can describe changes to particle movement when particles are heated or cooled

Learning intention

To understand how heat affects the movement of particles in solids, liquids and gases

Success criteria

SC 1: I can describe changes to particle movement when particles are heated or cooled.

SC 2: I can explain changes to the properties of solids, liquids and gases when particles are heated or cooled.

FIGURE 3.5.1 Heat affects people, and causes changes in the environment.

Heating, cooling and energy

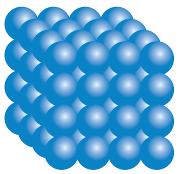
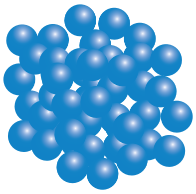
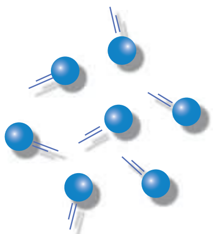
Energy is defined as the 'ability to do work'. This means that energy can move or change things.

Energy is stored in different ways, such as in thermal, electrical or **kinetic energy** stores. It can be transferred through processes such as heating, sound and light, which all cause change or movement.

How does energy affect particle movement?

You can model how particles move in the three states of matter as shown in Table 3.5.1.

TABLE 3.5.1 The behaviour of particles in solids, liquids and gases

Solid	Liquid	Gas
Particles vibrate backwards and forwards but stay in the same position. 	Particles move slowly past each other. 	Particles move in all directions at different speeds, some very fast. 

KEY TERMS

energy the ability to do work; can be in many forms including heat, movement and electricity

kinetic energy energy possessed by a moving object

KEY TERM

temperature a measure of the average kinetic (movement) energy of particles in a substance that results in how hot or cold the substance is

Changes in **temperature** are related to the energy that particles have and how fast they move.

When temperature increases (heating), 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 temperature decreases (cooling), particles move slower. As particle movement slows, there are fewer collisions between particles, and they move closer together.

As the energy of particles increases or decreases, the temperature of the substance made from these particles will also increase or decrease. Therefore, temperature is a measure of the energy of particles.

SC 1 CHECK YOUR UNDERSTANDING

Compare the particle movement in gas when it is heated and when it is cooled.

KEY TERMS

expand to increase in size
contract to decrease in size

SC 2 I can explain changes to the properties of solids, liquids and gases when particles are heated or cooled

Heating and cooling

Heating is the opposite of cooling. Warming something up requires transferring energy into it, while cooling involves transferring energy away.

As you have learnt, when particles are heated and cooled, their energy and movement change. These changes in particle movement affect the properties of solids, liquids and gases.

Scifile

Popcorn popping

When you heat popcorn kernels, the water inside the kernel turns to steam (a gas) and expands. The pressure builds until the kernel bursts open, turning inside out and creating a tasty snack. The heat makes the particles move faster and explode.

What do you observe when the movement of particles changes?

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 slower and closer together because they have less energy. This will cause the substance to **contract**.

Examples of a solid, liquid and gas expanding and contracting are shown below.

Railway lines

When solids are heated and expand, the material often bends or cracks.

Most solids can expand and contract slightly without damaging the material. However, if these changes are fast and happen many times, the attractions between the particles in the solid will be weakened until they can no longer hold the solid together and cracks will form.

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 3.5.2) or crack.

FIGURE 3.5.2 Heat has caused the solid metal in the railway lines to expand, making it bend.

Thermometers

Liquids will expand slightly when heated and contract when cooled.

For example, the liquid in a thermometer 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 3.5.3).

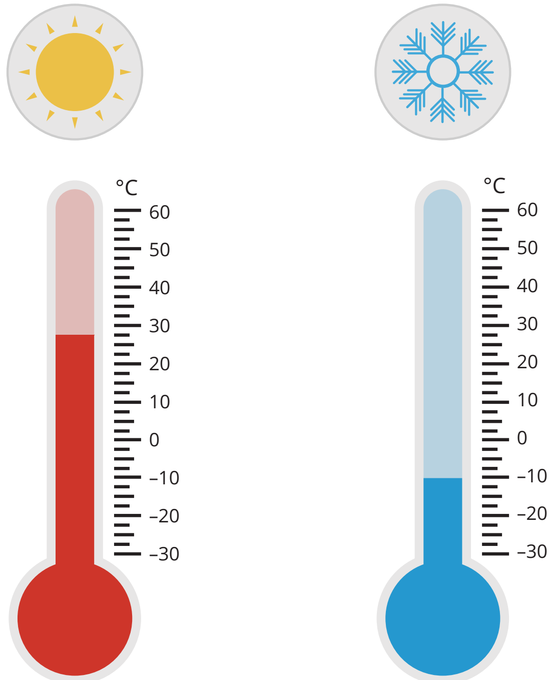


FIGURE 3.5.3 You can use thermometers to measure temperature because the liquid inside them expands and contracts with changes in temperature.

Hot air balloons

Gases will expand a lot when heated. When a gas expands, it becomes lighter and less **dense** as the particles spread out.

Hot air rises because its particles move faster, causing the air to expand and become lighter and less dense. Cool air sinks because its particles move slower, causing the air to contract and become heavier and denser. For example, when the gas in a hot air balloon is heated, it becomes lighter than the cooler air around it, allowing the balloon to rise and float in the air (Figure 3.5.4).

KEY TERM

dense containing a lot of matter in a small space

FIGURE 3.5.4 Hot air balloons over Sydney

SCIENCE IN SOCIETY

The risks of expansion caused by heat

The fact that solids expand when they get hotter and contract when they cool down can cause problems when building structures. The bigger the structure, the bigger the problem because the expansion and contraction will also be larger. The Australian climate can provide extreme variation in temperatures through the year, which can add to the risks.

The problem of solid expansion and contraction in bridges can be solved by using an expansion joint.

Expansion joints (Figure 3.5.5) are small but crucial components in bridges. 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 3.5.5 An expansion joint joins 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.

In colder weather, such as a frosty morning in Melbourne, the materials will contract or shrink. Expansion joints ensure that the bridge can handle this shrinking without causing damage.

The West Gate Bridge in Melbourne (Figure 3.5.6) has several expansion joints to accommodate the city's changing temperatures. Without these joints, the bridge would be at risk of serious damage.

FIGURE 3.5.6 Thousands of cars travel across the West Gate Bridge in Melbourne every day.

So, next time you cross a bridge, remember the expansion joints. They might be small and out of sight, but they play a big role in keeping bridges safe and durable, no matter the weather conditions.

SC 2 CHECK YOUR UNDERSTANDING

Compare how the properties of a metal rod change when heated to how the properties of a balloon change when heated. Explain any differences between the two.

Lesson review

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

1 Describe what happens to the movement of particles when they are heated.

2 Explain what happens to the movement of particles in a liquid when it is cooled.

3 Predict what happens to the hardness of a piece of rubber band when it is heated. Explain the reasons for your answer.

4 Expansion joints are added to large structures.
   a Explain, in terms of particles, what will happen to the solid materials used in the construction of bridges as temperatures increase and decrease.
   b Explain how expansion joints reduce damage to structures when the temperature increases.
   c Describe the required properties of materials used in expansion joints.

5 Using particle theory, predict what will happen to a football when it is left in the sun on a hot day.

3.6 How a thermometer works

Learning intention

To be able to develop and test a hypothesis to explore the particle model

Success criteria

SC 1: I can predict the effect of heat on a liquid using particle theory.

SC 2: I can measure accurate experimental readings to test the prediction.

SC 3: I can evaluate how well the experiment tested the hypothesis.

FIGURE 3.6.1 Thermometers operate by measuring the expansion and contraction of substances due to changes in temperature.

SAFETY NOTES

- Avoid sucking any liquids into your mouth.
- The hot water should be no hotter than 60°C.

Introduction

Heating a substance increases the energy of its particles, causing them to move faster and spread further apart. The more energy the particles receive, the more their movement increases. As they move, they collide with other particles, pushing them apart and causing the substance to expand. This is a cause-and-effect relationship—adding energy increases the temperature, which in turn causes expansion.

In this practical investigation, you will make a thermometer (Figure 3.6.1) to investigate how the expansion of a liquid can be used to measure temperature change.

Background

When the temperature increases, particles in substances gain energy and move more. This can cause the substance to expand. This can cause problems, such as cracking or bending of solids, and explosions of gases. But can you use this property for a useful purpose?

In this practical investigation, you will make a thermometer to investigate how the expansion of a liquid can be used to measure temperature change.

Aim

To explore whether the expansion and contraction of a liquid can be used to measure its temperature

Materials

- 250 mL conical flask
- food dye
- clear drinking straw
- modelling clay (plasticine)
- water (cold, room temperature and hot)
- ice
- permanent marker pen
- stopwatch/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.

Hypothesis

In your notebook, write a hypothesis that describes how the volume of water will change when the temperature is increased and when the temperature is decreased.

In this investigation, the volume of the water is the dependent variable, and temperature is the independent variable.

GO TO
Toolkit section 1.3, Hypotheses and predictions

Prediction

What will you observe when the water in the flask is heated and then cooled? Write your prediction in your notebook.

Method

Making a thermometer

1. Fill the 250 mL conical flask with room temperature water to almost full.
2. Add 2–3 drops of food dye to the water.
3. Insert the clear drinking straw into the flask.
4. Use the modelling clay (plasticine) to make an airtight seal over the top of the flask, with the straw going through the middle of the modelling clay, as shown in Figure 3.6.2.

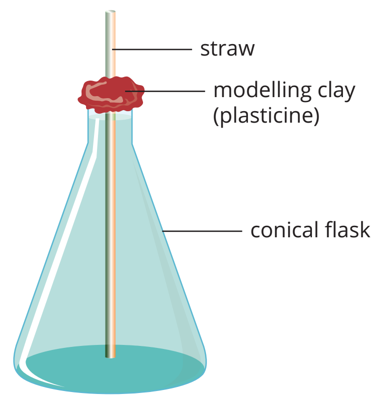


FIGURE 3.6.2 Seal the top of the flask with modelling clay.

Setting up the thermometer

5. Carefully blow into the drinking straw for a couple of seconds. Water should rise up the straw. Blow into the straw until the water level stays about 1 cm above the modelling clay plug.
6. Use the marker pen to mark this water level, as shown in Figure 3.6.3. Your 'thermometer' is now ready to use.

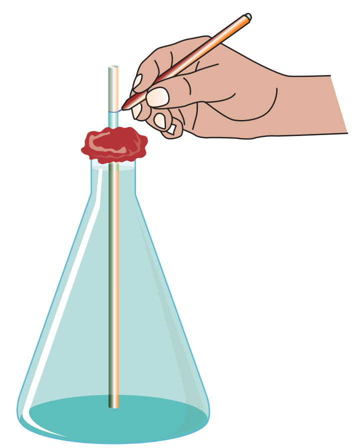


FIGURE 3.6.3 Use a marker pen to mark the water level.

Using the thermometer

7. Hold the flask in your hand to warm the flask for a couple of minutes. Use the permanent marker to mark the maximum height that the water reaches in the straw.
8. Half-fill a container with hot water.
9. Place the flask in the hot water for 2 minutes. Use the permanent marker to mark the maximum height that the water reaches in the straw.
10. Half-fill a container with cold water and ice.
11. Place the flask in the ice water for 2 minutes. Mark the minimum height that the water reaches in the straw.

Results

Record your observations in a table in your notebook.

Conclusion

Write a conclusion for your investigation in your notebook by answering the following questions.

1 How accurate was your prediction?
2 What caused the observations that you saw? This should relate back to your hypothesis.
3 How well do you think your thermometer could be used to measure or compare temperatures? Use evidence from your investigation to answer this question.
4 Thermometers usually do not use water but instead use coloured alcohol (ethanol). Suggest a reason why alcohol might be better than coloured water for measuring temperature.

GO TO
Toolkit section 4.1, Evaluating investigations

Evaluation

How well do you think your investigation tested your hypothesis? Record your evaluation in your notebook.

3.7 Particles and changes of state

Lesson overview

Particle theory helps explain the properties of solids, liquids and gases. It also explains what happens when a solid melts into a liquid, a liquid evaporates into a gas, and 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.

Observing something as simple as an ice cube melting and imagining what is happening to the tiny particles inside helps you understand and predict the behaviour of all substances.

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.

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.

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. Heating increases energy, causing particles to move faster and spread further apart. Cooling 'removes' energy, slowing particles down, bringing them closer together. As particle movement changes, the attractive forces between them can weaken or strengthen, potentially leading to a change of state.

KEY TERMS

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

evaporation the change of state in which a liquid changes into a gas at the surface of the liquid

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.

Heating can cause:

- **melting** – a solid changing into a liquid; the temperature at which this occurs is called the **melting point**
- **evaporation** – a liquid changing into a gas.

For example, when solid ice is heated, it changes to liquid water (Figure 3.7.1). 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.

FIGURE 3.7.1 An ice cube is melting; imagine what is happening to the particles.

Decreasing energy (cooling)

Decreasing the energy of a substance by cooling causes the particles to move more slowly and move closer together. As the particles cool down and move more slowly, the attractions between them become strong enough to hold the particles close together.

Cooling can cause:

- **freezing** – a liquid changing into a solid; the temperature that this occurs at is called the **freezing point**
- **condensation** – a gas changing into a liquid.

For example, when liquid water is cooled, it changes to solid ice. With less energy available, the particles slow down. The attractions between the particles become stronger, and the liquid water freezes and changes to solid ice.

KEY TERMS

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

condensation a change of state in which a gas is cooled and forms a liquid

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 3.7.2.

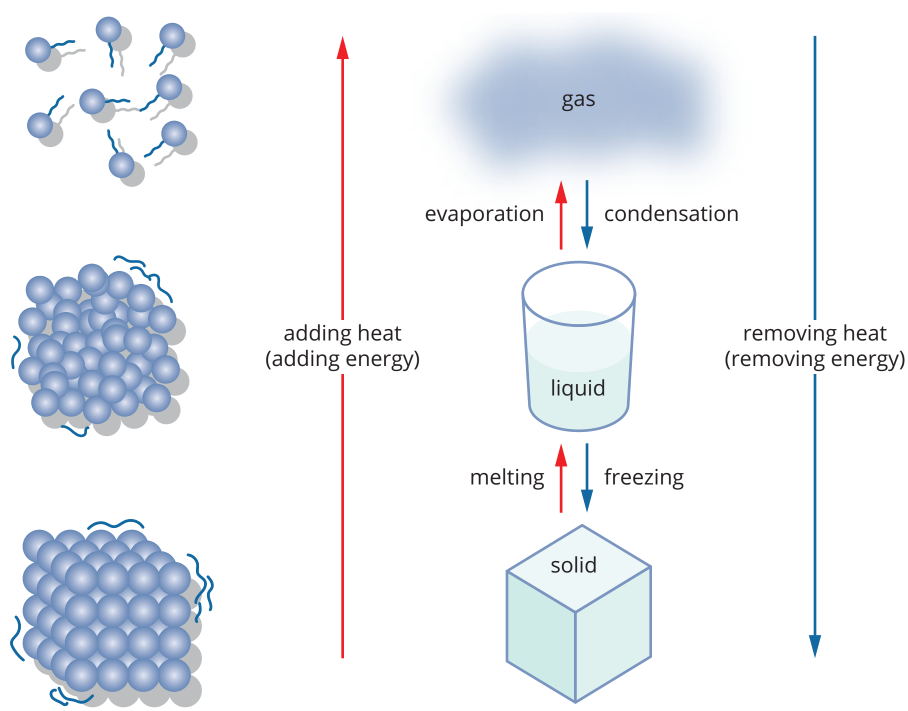


FIGURE 3.7.2 Changes of state are caused by heating (increasing energy) to particles, while the opposite processes occur if particles are cooled (decreasing energy).

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 (Figure 3.7.3), when it reaches the melting point of the substance. 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 3.7.3 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; for example, the formation of solid iron, as shown in Figure 3.7.4.

FIGURE 3.7.4 Liquid iron becoming a solid

The difference between evaporation and boiling

Evaporation is the process of liquid changing into gas, and it occurs on the surface of the liquid. You can't normally see it happening, except that the level of the liquid will go down as the liquid turns into a gas. Once a liquid reaches a certain temperature, it starts to turn to gas below the surface as well. This causes bubbles to form in the liquid and rise to the surface. The bubbling of a liquid when it is heated is called **boiling**.

Boiling point

The temperature at which a liquid boils is called the **boiling point**. Once a liquid reaches its boiling point, such as the water shown in Figure 3.7.5, it will stay at that temperature until all the liquid has evaporated.

FIGURE 3.7.5 Boiling water; note that the boiling occurs throughout the liquid, not just at the surface.

Melting and boiling points

Some examples of melting and boiling points are given in Table 3.7.1.

TABLE 3.7.1 The melting points and boiling points of some common substances

Substance	Melting point (°C)	Boiling point (°C)	State at room temperature
water	0	100	liquid
mercury	−39	357	liquid
ethanol (alcohol)	−114	78	liquid
silver	961	2193	solid

KEY TERMS

boiling a change of state in which a liquid is heated and changes to a gas within the liquid

boiling point the temperature at which a liquid boils

Scifile

Boiling water on a mountain top

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.

KEY TERMS

steam hot invisible gas given off as water is boiled (which often then forms a visible cloud of water droplets)

sublimation the change in state from a solid into a gas

The difference between water vapour and steam

Water vapour, like many gases, is invisible. The particles in a gas are too small to be seen. As the boiling point of water is quite high (100°C), water vapour in the air will quickly condense back to a liquid.

This causes very small droplets of liquid water to form in the air. This is what is often called steam. However, the correct term for this is 'wet steam' because it is a mixture of **steam** and water droplets that have condensed in the air.

This process is why the water vapour in your breath forms visible clouds when you breathe out on a cold day (Figure 3.7.6).

FIGURE 3.7.6 The condensation from your breath on a cold day is made of tiny droplets of liquid water mixed with water in the gas state, floating in the air.

Sublimation

When some solid substances are heated, they change to a gas, bypassing the liquid state. The reasons for this are quite complex, but it is linked to the strength of the attractions between particles and the pressure of the air around the substance.

If the strength of 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 to 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 3.7.7) is called dry ice, and it changes from a solid to a gas when it is heated.

Another example of sublimation occurs in iodine, which changes to a purple gas when it is heated (Figure 3.7.8).

FIGURE 3.7.7 Dry ice is a solid that changes into a gas when heated, in a process called sublimation, and the white vapor around the solid dry ice is gas.

FIGURE 3.7.8 Iodine subliming as it is heated. The purple vapor is iodine gas.

The reverse process of sublimation is called **deposition**. This is when a gas changes to a solid, bypassing the liquid state.

KEY TERM

deposition the change in state from a gas to a solid, bypassing the liquid state

SC 2 CHECK YOUR UNDERSTANDING

Explain why water turns into ice when cooled below 0°C.

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 vapour condenses into liquid water.

3 Some substances will convert straight from a solid to a gas when heated.
   a What is the term for this type of change of state?
   b Name one 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.

5 When you breathe out on a cold day, you can sometimes see your breath as a cloud or mist. Explain why you can see this mist even though air is invisible.

3.8 The process of evaporation

Learning intention

To understand the factors that affect the evaporation of a liquid

Success criteria

SC 1: I can describe familiar examples of evaporation.

SC 2: I can explain changes that occur to particles during evaporation.

Lesson overview

On a hot day when you are being active, your body might sweat as it tries to keep you cool. It is not the sweat that cools you down, it is the process of evaporation that cools your body. Particles in the water, which is the main component in sweat, absorb heat from your skin. As the water particles separate from each other, the liquid water turns into water vapour. This is evaporation in action.

Evaporation occurs in many situations, including clothes drying on a rack and puddles of water disappearing after a rain shower. As the climate warms up, increased rates of evaporation may cause problems, such as lack of water for growing crops and droughts in certain parts of Australia and the rest of the world.

In this lesson, you will learn about how a range of factors affect the process of evaporation and how particle theory can help to explain these processes.

SC 1 I can describe familiar examples of evaporation

The process of a liquid changing into a gas is called evaporation. This process occurs when the liquid absorbs heat energy from its surroundings.

Controlling body temperature

Humans are warm-blooded animals. This means that your body can use a variety of processes to maintain a constant temperature around 37°C. The processes in your body work best at 37°C.

Temperatures that are too low can cause hypothermia, a condition that can lead to confusion, uncontrolled shivering and eventually unconsciousness.

Temperatures that are too high can cause hyperthermia, a condition that can lead to heat stroke, cramps or dizziness.

Keeping your body cool

One of the mechanisms that humans use to keep their body at the correct temperature is sweating. Sweating is when the body releases liquid water through pores in the skin.

This water then absorbs energy from the body as it evaporates into water **vapour**.

Sweating helps to cool the body because the liquid sweat is cooler than the body, so energy transfers from the body to the water. The energy is absorbed by water particles, and this extra energy is enough to make the particles break away from each other and evaporate.

So, it is not really the sweating (Figure 3.8.1) that cools you down; it is the evaporation of the sweat.

KEY TERM

vapour matter that has been produced by evaporation from a liquid; can be a pure gas, as in water vapour in the atmosphere, or a mixture of a gas and small droplets of liquid

FIGURE 3.8.1 The evaporation of sweat from the skin takes heat energy away from the body.

Other examples of evaporation

Evaporation occurs all around us. Examples include clothes drying on a clothesline, using a steam iron, extracting salt from salt water and drying your hair with a hair dryer.

In all these situations, different factors affect how fast evaporation occurs, but they all involve liquid particles gaining energy and separating from each other to form a gas.

The difference between a vapour and a gas

The behaviour of particles in a vapour and a gas are the same, but substances will be referred to as a 'vapour' or a 'gas' depending on their state at room temperature.

If a substance is liquid at room temperature and it has evaporated, the substance produced is often called a vapour (because there would still be some liquid present). Vapours can generally turn back into a liquid easily, either by being allowed to cool or applying pressure to the vapour.

For example, you might have heard of 'water vapour' or 'petrol vapour'. These substances are referred to as vapours because water and petrol are both liquids at room temperature. Petrol vapour is a risk at service stations (Figure 3.8.2) because it can catch fire very easily.

FIGURE 3.8.2 Smoking is banned near petrol pumps because the petrol vapour is highly flammable.

The word 'gas' is used for substances that are gases at room temperature and can only be converted into the liquid form by cooling them significantly or applying extremely high pressure.

For example, oxygen and carbon dioxide are both gases at room temperature because they have boiling points well below room temperature. This is why they are called 'oxygen gas' and 'carbon dioxide gas'.

SC 1 CHECK YOUR UNDERSTANDING

Using the idea of evaporation, explain why clothes dry faster on a sunny day.

SC 2 I can explain changes that occur to particles during evaporation

When a liquid is heated, the particles' kinetic energy increases, making the particles move faster. This increased movement reduces the attractions between the particles so the particles can separate and behave like a gas (Figure 3.8.3).

Using an analogy for the particle model, such as marbles, can help you to understand evaporation. Marbles close together and moving slowly represent a liquid. As the marbles move faster, they bump into each other and move further apart. The marbles moving and separating represents the process of evaporation, and the marbles spaced far apart represent a gas.

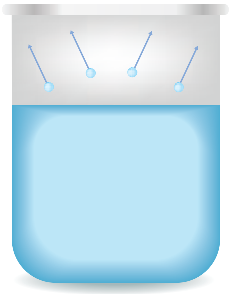


FIGURE 3.8.3 Evaporation involves particles 'escaping' from the liquid.

Rate of evaporation

Evaporation requires the particles to gain enough energy to move fast enough to separate from other particles. The rate of evaporation is how quickly the process is occurring. It can be thought of as how many particles escape from the liquid and become part of the vapour each second. The factors that affect the rate of evaporation are the:

- temperature of the surroundings—the hotter the liquid, the more energy the particles have
- strength of the attractions between the particles in the liquid—the stronger the attractions, the more energy they need to separate from each other
- surface area of the liquid—the larger the surface of the liquid (such as in a spray), the more chance for the particles to separate from each other
- mass of the particles—the heavier the particles, the more energy they need to get moving.

SC 2 CHECK YOUR UNDERSTANDING

Describe two things that have to occur for a particle to evaporate from the surface of a liquid.

Lesson review

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

1 Describe an example of evaporation you might observe in your daily life and explain the process.

2 Describe the changes in particle energy and movement when a drop of water evaporates from your skin and explain how this cools you down.

3 Describe how the movement of particles changes during evaporation compared to how their movement changes during boiling.

4 Evaporation can occur in a range of situations and the rate of evaporation will depend on a range of factors.

- a Explain why a glass of water left in a room will eventually evaporate even without direct heat.
- b Describe the role of wind in the evaporation of water from a lake.
- c Compare how quickly evaporation occurs in a shallow dish compared to a deep bowl, assuming there is the same amount of water in both.

3.9 Rates of evaporation

Introduction

The process of liquids turning into vapours or gases happens all around you. This process is called evaporation. Evaporation can be fast, such as drying hair with a blast of hot air, or it can be slow, such as waiting for clothes to dry on a cool day (Figure 3.9.1).

There are many things that affect how fast liquids evaporate, including the properties of the substance and its surrounding environment.

In this practical investigation, you will investigate the rate of evaporation of two different liquids. The rate of evaporation is how quickly the process of evaporation is occurring. You will use scientific knowledge to predict a result and to decide what variables need to be kept constant. 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 develop and test a hypothesis relating to a change of state

Success criteria

SC 1: I can develop a hypothesis based on independent and dependent variables.

SC 2: I can conduct a safe and valid experiment to test a hypothesis.

SC 3: I can evaluate how well an experiment tests a hypothesis.

FIGURE 3.9.1 Clothes drying through the evaporation of water

Background

There are several factors that influence the process of evaporation. In this practical investigation, you will investigate how the rate of evaporation varies between two different substances—water and ethanol (alcohol).

- Water particles are lighter than ethanol particles.
- The attractions between water particles are stronger than the attractions between ethanol particles.
- The boiling point of water is 100°C.
- The boiling point of ethanol is 78°C.

Using this information, you will use develop a hypothesis and use two different methods to test it. In this investigation, the substance used (water and ethanol) is the independent variable and the rate of evaporation is the dependent variable.

Aim

To develop and test a hypothesis relating to the rate of evaporation of a liquid

Hypothesis

Use your knowledge of particle theory and your own experiences to write a hypothesis in your notebook.

GO TO
Toolkit section 1.3, Hypotheses and predictions

Prediction

State a prediction based on your hypothesis for each of the two methods, A and B, below.

Materials

- 10 mL water
- 10 mL ethanol
- 1 cotton bud
- 250 mL beakers (or similar objects to act as supports)

SAFETY NOTE

- Ethanol is extremely poisonous so do not sniff or taste it. It irritates eyes and cuts, so always wear safety glasses and gloves when handling the ethanol.

- 2 × 100 mL beakers
- 1 sheet thick paper towel
- pencil
- sticky tape
- 30 cm plastic ruler
- plastic tweezers
- rubber 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

Read Methods A and B and design two tables in your notebook to record your observations.

Method A: Visual check

1. Dip one end of a cotton bud into water.
2. Use the end of the cotton bud with water on it to paint a streak of water on a sheet of paper towel.
3. Dip the other end of the cotton bud into ethanol (alcohol).
4. Use the end of the cotton bud with ethanol on it to paint an identical streak of ethanol on the same sheet of paper towel, as shown in Figure 3.9.2.
5. Lay the sheet of paper towel on your workbench and leave it to dry. Label the streaks 'water' and 'ethanol'.
6. Observe the paper towel and record in your notebook which streak of liquid evaporates first. (You can carry out Method B while you are observing the paper towel.)

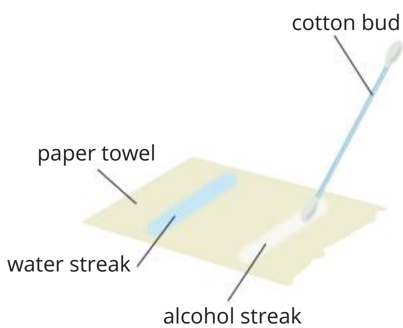


FIGURE 3.9.2 Method A: Placing the liquids on the paper towel

Method B: Balancing paper towel

1. Use sticky tape to attach a pencil to two beakers, as shown in Figure 3.9.3. Make sure that the pencil cannot move.

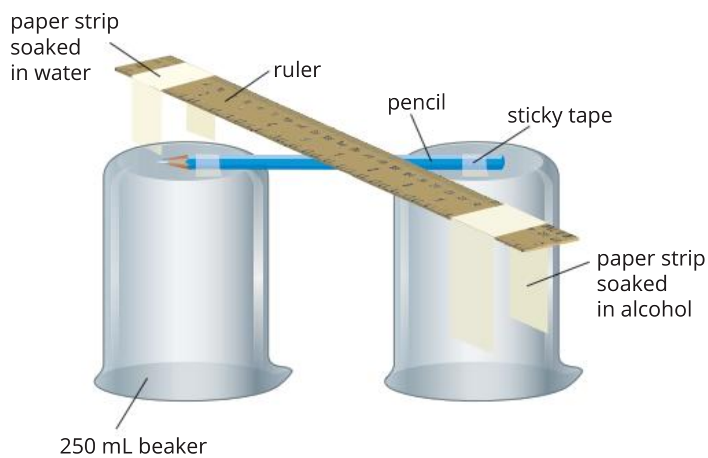


FIGURE 3.9.3 Method B: Setting up the balance

2 Pour 10 mL of water into one 100 mL beaker and 10 mL of ethanol into the other 100 mL beaker. Label the beakers 'water' and 'ethanol'.

3 Cut two 3 cm strips from a sheet of paper towel. Label one strip 'W' using a pencil.

4 Use the plastic tweezers to dip the strip of paper towel marked 'W' into the beaker of water so that it soaks up all the water.

5 Drape the paper towel soaked with water over one end of the ruler.

6 Use the plastic tweezers to dip the other strip of paper towel into the beaker of ethanol so that it soaks up all the ethanol.

7 Drape the paper towel soaked with ethanol over the other end of the ruler.

8 Balance the ruler and the strips of paper towel on the pencil.

9 Observe what happens to the ruler as the substances start to evaporate. Record in your notebook which end of the ruler moves upwards.

Results

Answer the following questions in your notebook.

1 a In Method A, which streak of liquid seemed to evaporate the quickest?
  b What observation did you use to discover this?

2 a In Method B, which liquid seemed to evaporate the quickest?
  b What observation did you use to discover this?

Conclusion

Answer the following questions in your notebook to capture your learning from this investigation.

1 Review your hypothesis and your results. Explain how well your results from the two methods supported your hypothesis.

2 Describe what you learnt about the behaviour of water and ethanol from completing this investigation.

3 What variables were kept the same (controlled variables) in the two methods?

4 Compare and contrast the strengths and weaknesses of the two methods used to test the hypothesis.

5 Explain why it is good scientific inquiry practice to use more than one method to test a hypothesis.

6 Suggest another way of comparing the loss of mass from the paper towel strips in Method B.

3.10 Freezing and condensing

Learning intention

To understand the change of state from a liquid to a solid and from a gas to a liquid

Success criteria

SC 1: I can identify familiar examples of freezing and condensation.

SC 2: I can compare the changes that happen to the movement and arrangement of particles during freezing and condensation.

SC 3: I can predict, and explain in terms of particles, what will happen when liquids and gases are cooled.

FIGURE 3.10.1 Liquid water droplets caused by condensation of water vapour on the outside of a cold glass

HINT

Remember that the freezing point and melting point of a substance are the same temperature.

Lesson overview

When a substance is cooled, its particles transfer energy to the surroundings. This causes them to move more slowly, and the properties of the substance change. A liquid might freeze, a gas might condense into a liquid (Figure 3.10.1) and a solid might become more brittle. These changes occur not only because the particles have less energy but also because of shifts in how they are arranged.

You can observe these changes in water every day—for example, when liquid water freezes into ice or when water vapour condenses into visible steam as it escapes from a boiling kettle. Similar changes of state also occur in many other substances, including food, such as melting ice cream, and fuels, such as petrol condensing.

In this lesson, you will learn how the changes of state from a liquid to a solid and from a gas to a liquid can be explained using particle theory.

SC 1 I can identify familiar examples of freezing and condensation

Freezing

Freezing is the process of a liquid forming into a solid. This occurs when snow or frost is formed or when an icy pole becomes solid in a freezer.

You may be used to thinking of freezing in terms of things that contain water, such as snow and icy poles. These substances freeze when it is very cold because water has a freezing point of 0°C. But freezing does not only happen at very cold temperatures. Some substances have freezing points above room temperature and so will change from liquid to solid when it is not cold. For example, liquid gold will freeze (become solid) when its temperature falls below 1064°C (the freezing/melting point of gold) as shown in Figure 3.10.2.

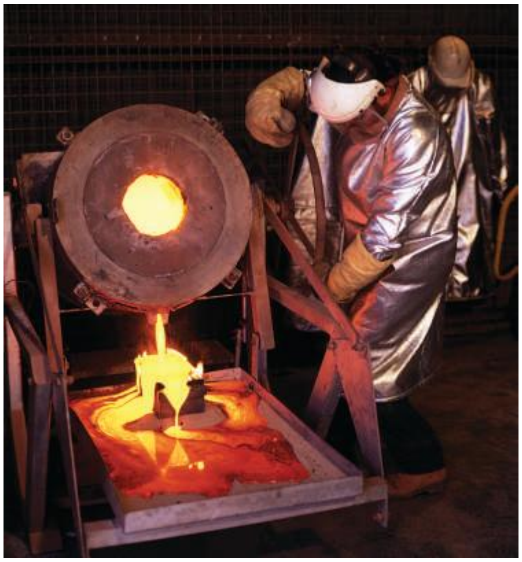


FIGURE 3.10.2 A gold worker pours liquid gold into a mould for it to solidify.

The difference between liquid and molten

The term **molten** is used to describe the liquid state of a substance that is a solid at room temperature, such as molten iron or molten gold. However, the behaviour of liquid particles and molten particles is the same.

KEY TERM

molten the liquid state of a substance that is normally a solid at room temperature

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 3.10.3) will condense into liquid nitrogen if its temperature falls below the boiling point of nitrogen (−196°C).

FIGURE 3.10.3 Liquid nitrogen being used to make ice cream

SC 1 CHECK YOUR UNDERSTANDING

Explain what condensation is and describe three examples.

SC 2 I can compare the changes that happen to the movement and arrangement of particles during freezing and condensation

When energy is transferred away from a substance as it cools, its particles have less kinetic energy. This means they move less and move closer together. This change in the behaviour of particles can lead to changes in state.

When cooled, substances may change from gas into liquid (condensation) or liquid into solid (freezing).

Condensation and particles

Particles in a gas can attract other particles, but they are moving so fast and are so far apart that the attractions have little effect. An analogy for this is a few students spread out across a large school oval trying to get the attention of each other. The further apart the students are, the less effect they have on one another.

When energy is transferred away from a gas as it cools, its particles will move less and the spaces between the particles will become smaller. The attractions between the gas particles will have a greater effect as the particles move closer together, and there is a chance that the gas will turn into a liquid. This process is condensation.

Freezing and particles

When energy is transferred away from a liquid as it cools, its particles move less and move closer together. Particles in a liquid already have quite strong attractions between them, so the attractions have a greater effect. If the particles stay in fixed positions, a solid has been formed. This process is freezing.

Forming crystals

If the freezing process occurs slowly, the particles can form into regular arrangements, which can cause regular-shaped, often beautiful, solids to form. These are called crystals. Snowflakes (Figure 3.10.4) are examples of crystals.

FIGURE 3.10.4 Snowflakes are a solid structure formed from the freezing of liquid water.

FIGURE 3.10.5 The formation of ice on these vines actually keeps them warm.

How do freezing and condensing release energy?

When a substance changes from a gas to a liquid or from a liquid to a solid, its particles transfer energy to their surroundings. This 'released' energy can warm the surrounding environment.

This effect can be useful in cold climates. For example, spraying plants with water can help protect them from frost damage (Figure 3.10.5). As the water freezes on the plant, the energy released during the phase change provides warmth, reducing the risk of freezing damage.

For more details about preventing frost damage see the Science in Society section.

SCIENCE IN SOCIETY

Protecting crops from frost

Frost can be a big problem for farmers in Australia because it can damage or even destroy crops. When temperatures drop below the freezing point of water (0°C), ice crystals can form on plants. Because water has the unusual property of expanding when it freezes, this can cause the plant cells to burst and lead to serious damage. To protect their crops, Australian farmers use several methods to fight frost.

Using wind machines

One common method is using wind machines (Figure 3.10.6). These large fans are placed in fields and turned on during cold nights. The fans mix the warmer air from above with the colder air near the ground. The movement energy of the air and the increased temperature around the plants prevent frost from forming.

FIGURE 3.10.6 A wind machine designed to protect orange trees from frost

Frost irrigation

The technique of spraying crops with water is called irrigation. As the water freezes, it releases a small amount of heat, which helps keep the plants from freezing. This method works best for certain types of crops like strawberries and vegetables.

Covers

Farmers also use row covers or frost cloths (Figure 3.10.7). These are large sheets made of fabric or plastic that are draped over crops to trap heat from the soil. The covers act like blankets, keeping the plants warmer during frosty nights. They are especially useful for protecting smaller plants and seedlings.

FIGURE 3.10.7 Young fruit trees covered to prevent frost forming on them

Heaters

Some farmers use heaters that burn fuel to create heat and can be placed around the fields to keep the air temperature above freezing. While effective, they can be expensive and are usually used for high-value crops such as grapes in vineyards.
By using these strategies, Australian farmers can reduce the risk of frost damage and help ensure that their crops survive through to harvest time, even if the temperatures drop to below the freezing point of water (0°C).

SC 2 CHECK YOUR UNDERSTANDING

Compare the changes to the movement and arrangement of particles in water when it freezes to the changes as it condenses.

SC 3 I can predict, and explain in terms of particles, what will happen when liquids and gases are cooled

When does condensation occur?

Condensation and evaporation occur at the boiling point of a substance. The boiling point is the temperature that a liquid can be heated to before turning into a gas (evaporating). When a gas is cooled, it will change back into a liquid (condense) at the boiling point.

The boiling point of a substance will depend mainly on the strength of the attractions between the particles, and on the mass of the particles.

For example, water has a higher boiling point (100°C) than ethanol (78°C). So, water vapour at 90°C would condense, but ethanol vapour at 90°C would stay as a gas because this temperature is above the boiling point of ethanol.

When does freezing occur?

Freezing and melting occur at the freezing point (also called the melting point) of a substance. The freezing point of a substance is the same temperature as the melting point.

For example, liquid water will begin to change into solid ice at 0°C and freeze if the temperature drops below 0°C. Solid ice can also begin to change into liquid water at 0°C and melt if the temperature increases above 0°C. Ethanol has a freezing point/melting point of −144°C, so ethanol will stay liquid long after water has turned into a solid (Figure 3.10.8).

FIGURE 3.10.8 This glass is made of ice (frozen water), but the drink contains ethanol, so it will not freeze because ethanol has a lower freezing point than water.

Melting points and boiling points

Some examples of melting and boiling points are given in Table 3.10.1. You can use this data to predict the state of a substance. Placing the data on a number line (Figure 3.10.9) is a great way to visualise the states and how they relate to the boiling point and freezing point.

- At temperatures higher than the boiling point, the substance will be a gas.
- At temperatures lower than the freezing/melting point, the substance will be a solid.
- At temperatures between the freezing/melting point and boiling point, the substance will be a liquid.

TABLE 3.10.1 Melting and boiling points of some common substances

Substance	Freezing/melting point (°C)	Boiling point (°C)
ethanol (alcohol)	−114	78
chlorine	−101	−34
petrol	−60	95
water	0	100
aluminium	660	2470
silver	961	2193

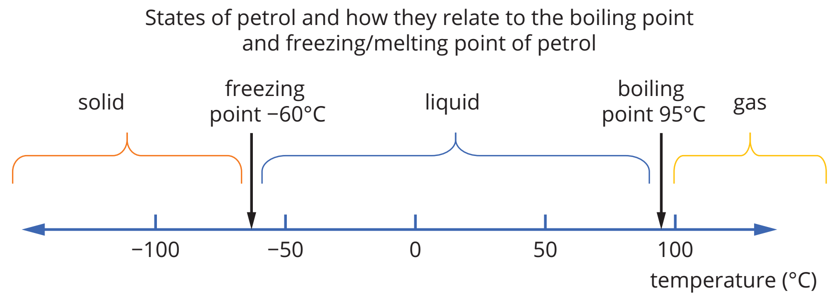


FIGURE 3.10.9 Using a number line is a good way to visualise this information

SC 3 CHECK YOUR UNDERSTANDING

Predict what will be observed if ethanol vapour is cooled to a temperature of −200°C. Explain the reasons for your prediction.

Lesson review

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

1 Describe what happens to the attractions between particles during freezing.

2 Identify an example of condensation you might observe in your daily life and explain the process.

3 Compare the processes of freezing and condensation in terms of changes to particle movement and energy that occur in the two processes.

4 Frost can damage crops on cold days and nights.
   a Describe what frost is.
   b Describe how wind machines can be used to prevent frost forming on crops. Use the idea of particles in your answer.

5 Consider the boiling and freezing points listed below.

Substance	Freezing point (°C)	Boiling point (°C)
chlorine	−101	−34
hexane	−95	69
water	0	100
silver metal	961	2193
mercury metal	−39	257

From this list, name:
   a the substances that would be solids at room temperature (25°C)
   b the substances that would be liquids at room temperature (25°C)
   c a substance that freezes if cooled from −50°C to −100°C
   d any substances that would melt and boil if heated from −20°C to 1000°C.

3.11 Investigating freezing

Introduction

Freezing is how you produce ice cubes from water, solid chocolate bars from melted chocolate or icy poles from fruit juice (Figure 3.11.1). Often it is important to freeze things quickly. What will affect how quickly liquids freeze and can you change the conditions to control the speed of freezing?

In this inquiry activity, you will design an experiment that investigates the rate of freezing. You will need to be scientific when choosing your variables and creative when deciding on a method to use for this task.

Learning intention

To be able to develop and test questions to explore freezing

Success criteria

SC 1: I can develop an investigable question that identifies an independent variable.

SC 2: I can design and evaluate a valid method, including the selection of equipment, to test the effect of an independent variable.

SC 3: I can write a conclusion based on evidence from the investigation.

Background

Freezing occurs when particles in a liquid transfer energy to their surroundings, causing their movement to slow down. As the particles move less, they arrange themselves into a solid structure. The temperature at which this happens is called the freezing point.

In this activity, the rate of freezing is the dependent variable.

The independent variable is something that changes the rate of freezing.

In this investigation, you will be selecting an independent variable to investigate. You will write an inquiry question about whether changing this independent variable will affect how quickly a liquid freezes.

FIGURE 3.11.1 Fruit juice icy poles

What makes a good inquiry question?

A good inquiry question is one that can be answered by carrying out an investigation. These are called investigable questions.

Possible inquiry questions for this investigation

The following are ideas for questions that you can use for this investigation. You can use one of these, change one of these or write your own question.

- Does cold water freeze faster than warm water?
- Does the shape of the container affect how quickly the water will freeze?
- Does the volume of water affect how quickly the water will freeze?
- Does saltwater freeze faster than fresh water?
- Do different fruit juices freeze at different rates?

Aims

- To develop a question for investigation that includes an independent variable
- To use equipment to test the effect of the independent variable
- To write a conclusion based on the results from your investigation

GO TO
Toolkit sections 1.1, Investigable questions and 1.2, Dependent, independent and controlled variables

Plan

Plan how you will carry out your investigation.

Brainstorm ideas for questions that you would like to investigate.

Think about the materials that you will need for your investigation. Materials that might be useful include:

- a thermometer or temperature probe
- measuring cylinders (10 mL or 25 mL)
- an ice cube tray
- small plastic cups
- stopwatch
- substances, such as salt, to add to the water (depending on the independent variable being investigated)
- access to water (possibly both hot and cold).

You could use 5–10 mL of water for each test (for example, in an ice cube tray or small plastic cup).

When you have chosen the question that you are going to investigate, write it down in your notebook and check in with your teacher.

HINT

To measure the rate of water freezing, you will need access to a freezer for around an hour. The rate of freezing can be influenced by environmental factors that change how quickly something cools. These factors include:

- the amount of liquid
- the type of liquid and if it is mixed with other substances
- the size and shape of the container that the liquid is in.

GO TO

Toolkit sections 2.1, Writing a method for an experiment, 2.4, Taking measurements in science and 5.3, Drawing scientific equipment

Design

Develop the method for your investigation using the guidelines below.

Write your step-by-step method in your notebook.

The steps in your method should be clear and easy to follow. A good test is to ask yourself 'If another student read these steps, would they know what to do?'

Consider the variables that will not change (the controlled variables) throughout your investigation. Mention the controlled variables in your method and describe how you are going to keep them constant throughout the investigation.

Plan what measurements or observations you will make and how you will record them.

Include safety information, including any potential risks.

Once you have designed your method, check in with your teacher for feedback.

Conduct

Make sure that the only thing that is changing in your investigation is the independent variable that you have chosen to investigate. The other variables (the controlled variables) must be kept the same throughout the investigation. You must follow your own safety information, as well as normal laboratory rules.

Recording data

Record the measurements and observations that you need to answer your inquiry question in your notebook.

Evaluate the method as you carry out the investigation. You can do this by making notes in your notebook, which will help you reflect on your investigation later.

KEY TERM
evaluate to assess the quality or value of something

Analysing data

Once you have completed your investigation, use the data you have collected to answer your inquiry question and write a conclusion. You may be asked to present a written or verbal report to justify your conclusions.

Improve

Identifying problems

Consider any problems that you had while carrying out your investigation. These could include:

- problems recording results (measuring the dependent variable) during the experiment
- making sure that the results were valid by keeping the controlled variables the same during the experiment
- considering the suitability of the chosen equipment for the experiment.

Write down any problems in your notebook.

Potential improvements

Consider how the experiment could have been improved by asking questions such as:

- How did others approach this task?
- What are the strengths of their ideas?
- Could some of these ideas be used to improve your own method?
- What other equipment could have been used?

Record your thoughts in your notebook and use these notes to help you evaluate your investigation in the 'Evaluate' section below.

GO TO
Toolkit sections 4.1, Evaluating investigations and 5.5, Writing a practical investigation report

Evaluate

Evaluate your investigation.

1. Describe how well the investigation answered your inquiry question.
2. If your investigation was not able to answer your inquiry question, suggest a reason why not. Think about whether the problem(s) were caused by the inquiry question, by the method, or by both.
3. Use your experience from this inquiry activity to explain what you think is meant by the term 'investigable question'.
4. Use your knowledge of particle theory to suggest an explanation for your results from this inquiry activity.

3.12 Exploring condensation

Learning intention

To be able to test a prediction using a valid experimental method

Success criteria

SC 1: I can state a prediction based on observations and knowledge of condensation.

SC 2: I can develop a conclusion based on observations from an experiment that I have carried out.

SC 3: I can identify possible sources of error and suggest improvements to the experimental method.

FIGURE 3.12.1 Condensation forming near the surface of a river

SAFETY NOTES

- Be careful when working with very hot water. Do not carry boiling water in beakers.
- Wait for the equipment to cool before clearing it away.

Introduction

Most common gases are invisible. They have no colour. Often, they only become visible when they condense to form liquids (Figure 3.12.1). This can result in the formation of tiny drops of liquids suspended in the air that form clouds. This is how clouds in the sky are formed from invisible water vapour in the atmosphere, and how clouds of smoke are formed from unburned fuel vapour escaping from the exhaust pipes of racing cars.

In this practical investigation, you will investigate how evaporation can occur, and how changes in temperature can affect the process of evaporation.

Background

Condensation is the process of a gas changing into a liquid. Condensation occurs when particles lose heat energy as a substance cools.

In this practical investigation, you are going to observe the condensation of water. The water vapour will be produced by hot water evaporating from beakers. Petri dishes under different conditions (hot, cold and room temperature) will be used to condense the water vapour back into liquid water.

Aim

To learn about valid experiments by testing a prediction related to condensation

HINT

A valid investigation is one that measures what it set out to measure.

Materials

- 2 × 250 mL beakers
- hot water
- thermometer
- 2 Petri dishes (preferably glass)
- ice cubes

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

Read the method and design a table in your notebook to record your observations.

1. Pour 100 mL of hot water (between 60–80°C) into each of the two beakers.
2. Place one ice cube in one Petri dish.
3. Pour a small amount of warm water in another Petri dish.
4. Position the two beakers close together and quickly place the Petri dishes on top of the two beakers as shown in Figure 3.12.2.

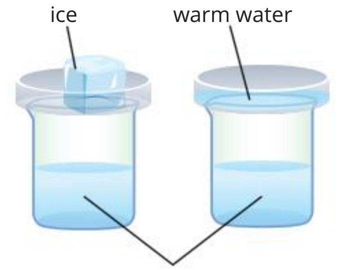


FIGURE 3.12.2 Petri dishes, one with an ice cube, and one with warm water, placed over the beakers of hot water

Prediction

In which Petri dish will you observe the most condensation? Write your prediction in your notebook and explain the reasons for your prediction.

Results

After 5 minutes, observe the underside of the two Petri dishes. In your results table, describe the amount of condensation formed on each Petri dish.

Conclusion

Write a conclusion for your investigation in your notebook. Note whether your results matched your prediction.

Evaluation

Complete the following questions in your notebook.

1. Describe how valid your investigation was.
2. Describe how you could make the investigation more valid.
3. Describe how you made the measurements of water accurate.
4. Describe how you could make the measurement of the amount of condensation more accurate.

GO TO
Toolkit sections 2.5, Mistakes and errors and 4.1, Evaluating investigations

3.13 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.

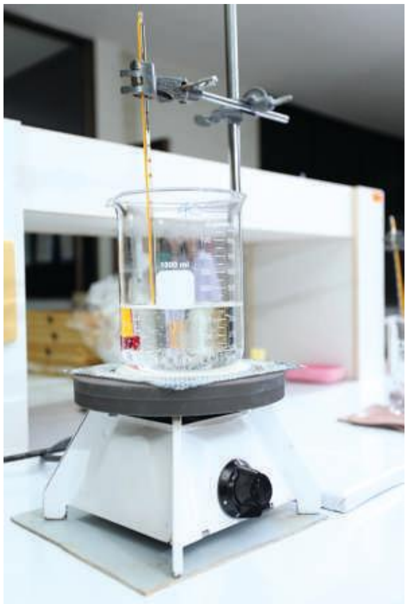


FIGURE 3.13.1 Water changes as it is heated from below its melting point to its boiling point.

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 3.13.1). The temperature data collected during this investigation provides evidence for the behaviour of particles in the water and the properties of water itself.

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 used in school science.

The second (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 (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

Materials

- 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.

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 3.13.2.

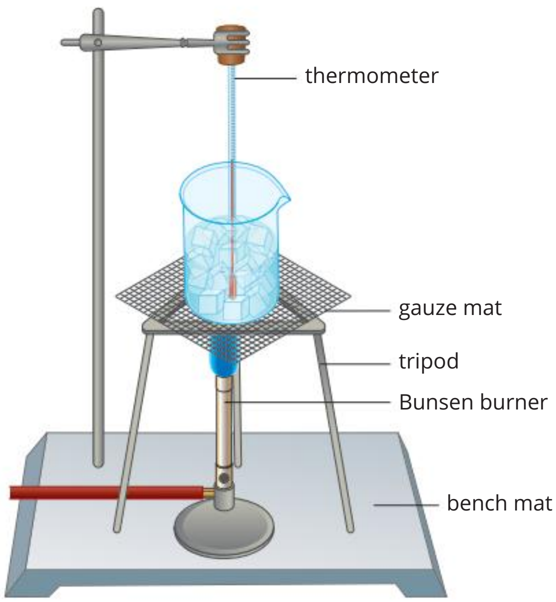


FIGURE 3.13.2 A clamp is used to hold the thermometer in the ice above the base of the beaker.

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 Continue recording the temperature every 30 seconds for about 3 minutes after the water boils.

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 about 15 minutes, possibly longer.

Determine how long and how often you will be recording results. Make sure your table will be big enough for all the results.

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 clearing it away.

GO TO

Toolkit sections 2.4, Taking measurements in science and 3.3, Designing a results table

GO TO

Toolkit section 3.4, Using line graphs and column graphs

KEY TERM

line graph a graph that uses lines to identify patterns and trends shown by data points from two sets of continuous measurements

GO TO

Toolkit section 3.5, Patterns and trends in data

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 Describe what happened to the temperature of the water between the times when the ice melted, and the water boiled.

2 Describe what happened to the temperature of the water as the water changed state.

3 In this investigation, heat energy was being provided by the Bunsen burner.

   a Predict how this energy was affecting the particles during the changes of state.

   b Predict how this energy was affecting the particles between the changes of state.

3.14 Solids, liquids and gases in the environment

Lesson overview

Changes of state happen all around you. Particle theory helps to explain when, why and how quickly they occur. Many of these changes are used to make and create things, and to control and regulate energy. Some materials are made up of more than one substance and can be made up of substances in more than one state of matter. This sometimes makes them hard to classify, but these unique properties of materials make them very useful in a range of situations, including in food and cosmetics.

In this lesson, you will learn how to predict and represent changes of state that you might experience in your life. You will also discover some of the properties of materials that seem to behave like more than one state of matter.

Learning intention

To understand how solids, liquids and gases undergo phase changes depending on their environment

Success criteria

SC 1: I can summarise phase changes that occur in solids, liquids and gases and give examples.

SC 2: I can describe and suggest reasons for changes to substances in different environments.

SC 3: I can explain why some materials have the properties of more than one state of matter.

KEY TERMS

phase another word for state (solid, liquid or gas)

reversible can occur in both directions; for example, freezing is the reverse of melting

SC 1	I can summarise phase changes that occur in solids, liquids and gases and give examples

With an understanding of particle theory and the particle model for solids, liquids and gases, you can explain how substances behave. The changes to particles that cause changes of state are summarised below. Another word for state is **phase**, so substances can be described as being in the solid phase, the liquid phase or the gas phase (Figure 3.14.1).

FIGURE 3.14.1 Water in a range of different states

Different states, or phases, of matter are formed when particles are arranged (based on the strength of attractions between particles) and move with different speeds (with different amounts of energy).

Changes of state, or phase changes, happen when there is a dramatic change of the arrangement and movement of the particles.

Phase changes can go in both directions, with freezing being the opposite of melting and condensation being the opposite of evaporation. This means that these changes of state are **reversible**.

Representations of particle theory

When communicating scientific information, the type of representation can be very important. Figures 3.14.2–3.14.4 summarise the three states of matter and the changes between them.

Each figure focuses on a different aspect of changes of state. Figure 3.14.2 shows the observable changes, Figure 3.14.3 includes how the behaviour of particles changes, and Figure 3.14.4 focuses on the role of energy in the process.

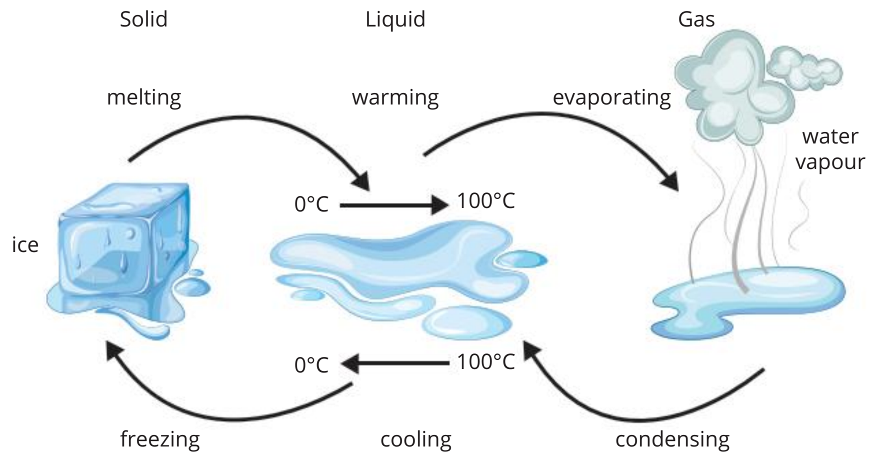


FIGURE 3.14.2 The three states (or phases) of water and the processes that cause them to change state

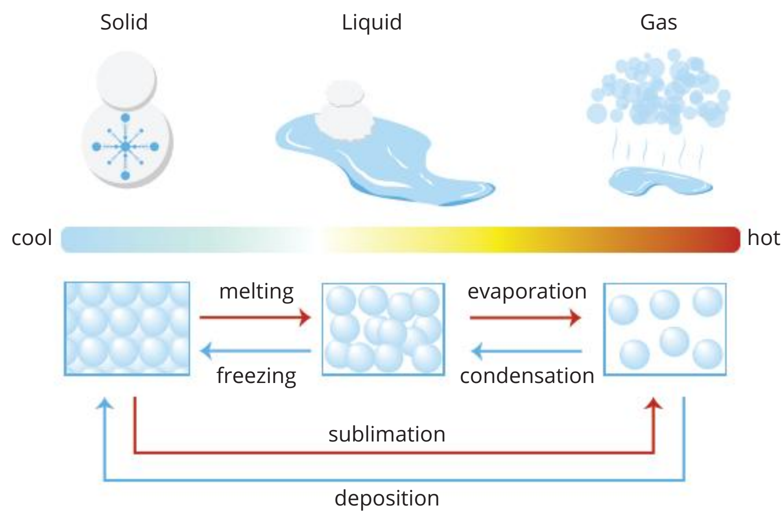


FIGURE 3.14.3 The three states of matter and the different particle arrangements in each

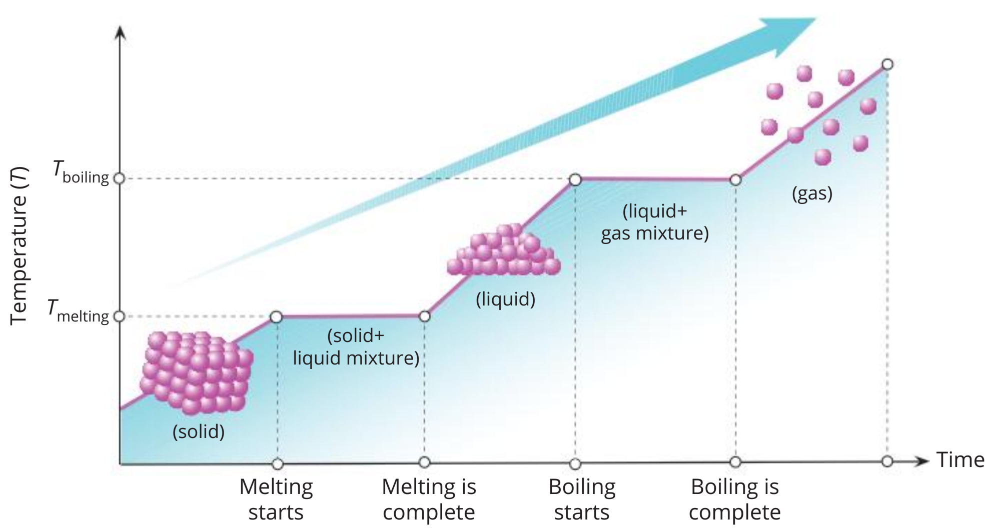


FIGURE 3.14.4 Changes of state from solid to liquid to gas as temperature increases over time and energy is absorbed by the particles

SC 1 CHECK YOUR UNDERSTANDING

Describe the phase changes that water can undergo as it moves through the environment.

SC 2 I can describe and suggest reasons for changes to substances in different environments

Changes of state occur all around you, all the time. They happen in washing, in cooking and in your body. Particle theory can be used to explain these changes and can allow you to predict what will affect the speed of these processes.

How to get dry dishes from a dishwasher

Heat from the washing process causes excess water to evaporate to water vapour as particles gain energy and separate.

Water vapour will condense back to steam because the temperature will be below the boiling point of water.

This steam will remain 'trapped' in the dishwasher until it is opened.

If dishes are still in the dishwasher, the tiny water droplets in steam might form into big drops of water on the dishes.

After a wash cycle, sometimes the door of a dishwasher is opened to let the steam out (Figure 3.14.5). But this does not always result in drier dishes. If the inside of the dishwasher cools down too much when the door is opened, water vapour may condense back onto the dishes. There is a delicate balance between changes of state that needs to be considered to get perfectly dry dishes.

FIGURE 3.14.5 Getting dry dishes requires an understanding of changes of state.

Why do barbeque gas bottles contain liquid?

Most barbeques use liquefied petroleum gas (LPG) (Figure 3.14.6), which can be sold in bottles. But how is this gas 'liquefied'?

LPG is a mixture of gases that all have a boiling point above normal room temperature.

The LPG is cooled to liquefy (condense) the gas into a liquid by reducing the energy of the particles.

The LPG is stored under high pressure, which forces the particles to stay close together, so the LPG stays in the liquid phase in the bottles.

As soon as the LPG escapes from this high-pressure situation, the liquid will evaporate back into a gas.

FIGURE 3.14.6 LPG gas is stored under pressure.

SCIENCE IN SOCIETY

Changes of state in air conditioners

The Australian climate means that air conditioners are a common sight in homes, schools and other buildings. There are two main types of air conditioners (ACs) but they all remove heat from the indoor air and transfer it outside of the building.

Evaporative air conditioners

These cool air through the process of evaporation of water. They draw warm outdoor air through water-saturated pads (Figure 3.14.7). The water evaporates, and as it does so it absorbs some of the heat energy from the warm air. This lowers the air temperature. A fan then circulates this cooled air throughout the building. This cooled air, however, is more humid as it contains more water vapour due to the cooling process.

FIGURE 3.14.7 Evaporative air conditioners are often used in regions of Australia with hot dry climates.

Unlike other ACs, evaporative coolers do not use refrigerants or compressors, making them energy-efficient and environmentally friendly. However, their cooling efficiency decreases with higher humidity levels, so these are best used in regions with a hot, dry climate, such as parts of inland Victoria and New South Wales, as well as areas around Perth and Adelaide.

Split system air conditioners

Split system ACs have an indoor unit and an outdoor unit (Figure 3.14.8). The indoor unit contains the evaporator coils and a fan, while the outdoor unit houses the compressor and condenser coils.

A chemical refrigerant, normally a hydrofluorocarbon, circulates between the two units through tubes made from copper metal.

FIGURE 3.14.8 The compressor unit of a split-system air conditioner.

The refrigerant transfers the heat from inside the building to the outside through the following steps.

- The refrigerant starts in the evaporator coils located in the indoor unit. As warm indoor air is drawn over these coils, the refrigerant absorbs the heat, causing it to evaporate and change from a liquid to a gas. This process cools the air, which is then circulated back into the room.
- The refrigerant vapour, carrying the absorbed heat, is pumped to the outdoor unit through copper tubing.
- In the outdoor unit, the gaseous refrigerant is compressed and then flows through the condenser coils. This is where it releases the absorbed heat to the outside air and condenses back into a liquid.
- The liquid refrigerant is then cycled back to the indoor unit, making it ready to absorb heat again.

The refrigerant's ability to change states from liquid to gas and back is essential to this heat transfer process. Because split systems do not rely on the evaporation of water, they work well in humid climates and are used all around Australia.

How do artificial snow machines work?

Snow machines (Figure 3.14.9) were invented in the 1950s but are being used more and more, partly due to the increasing temperatures caused by climate change.

Water vapour in the air will normally only condense to water and then snow if the temperature is well below the freezing point of water (0°C). To make the water particles come together to make solid snow artificially, compressed air is used to force the water out into the cold air. Because the water is forced into tiny droplets, it will cool more quickly.

Natural snowflakes normally start to form on tiny pieces of dust in the air. For artificial snow, tiny particles of proteins are added to the water to provide the pieces that the 'snow' can grow on.

FIGURE 3.14.9 As the climate warms, more snow machines are being used to keep ski fields open.

Why does water expand when it freezes?

The fact that water expands when it turns to ice can cause many problems, including glass bottles breaking when the liquid freezes inside the bottle (Figure 3.14.10). Water can also cause cracks in rocks and buildings to get bigger when the water expands as it freezes inside the crack.

In a liquid form, the particles can move and are able to get very close together.

When the particles pack together as a solid forms, they are forced into fixed positions.

Water particles are not a spherical (round) shape, which means that there are tiny gaps between the particles when they are forced to fit together as a solid.

This is why the volume of the solid ice is more than the volume of the liquid water.

FIGURE 3.14.10 A wine bottle will shatter as water freezes inside the bottle.

SC 2 CHECK YOUR UNDERSTANDING

Describe how the particles in a liquid behave in a hot environment compared to a cold environment. Include how these differences can result in changes of state.

SC 3 I can explain why some materials have the properties of more than one state of matter

Some substances are difficult to classify as just solid, liquid or gas. Their properties might be a combination of the characteristics of these three states of matter. For example, thick cream can be poured, but it also can have some properties of a solid.

Many materials like this are mixtures of two or more substances, which may be in different states.

Scifile

Why do icebergs float?

Most substances become denser when they freeze or solidify. However, due the arrangement of water molecules, ice is around 10% less dense than water. The lighter ice floats on the surface of the heavier water.

Around 10% of an iceberg is visible with 90% below the surface.

FIGURE 3.14.11 Meringue is a mixture of liquid egg white and air and is used in desserts such as pavlova.

For example, meringue (Figure 3.14.11) is a mixture of liquid egg white and air. Gels are a mixture of liquid and solid. So, these mixtures are difficult to classify as just solids, liquids or gases.

Mixtures and states of matter

See Table 3.14.1 for a summary of mixtures that are made from a combination of different states of matter. You should be able to think of some of your own examples of these.

TABLE 3.14.1 Types of mixtures

Type of mixture	Components	Description	Examples
gel	liquid and a solid	Gels are mainly liquid, but attractions between particles can keep the gel in a soft shape like a solid.	• energy gels for athletes • jam
foam	gas trapped in a solid or liquid	Foam can be a solid or liquid with gas trapped in 'bubbles' in the structure of the foam.	• meringue • gym mat
suspension	solid particles in a liquid	In a suspension, the solid will sink to the bottom of the liquid when left for some time.	• muddy water • flour in water
emulsion	two different liquids that normally do not mix	The liquids in an emulsion will not separate because of how they have been mixed, or another substance keeping the two components together. Emulsions are sometimes called colloids.	• milk • mayonnaise • paint
solution	can be any combination of liquids, solids or gases	In a solution, one substance is dissolved (completely mixed) into another.	• saltwater • air

SC 3 CHECK YOUR UNDERSTANDING

Handwash can be a foam or a gel. Compare the different properties of a foam and a gel and explain these differences in terms of states of matter and particles.

Lesson review

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

1 Phase changes can occur in all substances. Create a table with three headings as shown, and complete the table for six phase changes. Try to use a different substance for each example.

Phase change	Definition	Example

2 Describe the phase changes of water and carbon dioxide that can occur at room temperature and normal air pressure.

3 Compare the changes that occur to a solid and a gas when both are placed in a cold environment. Consider the behaviour of particles and suggest possible changes to the properties of the substances.

4 Design and complete a table to compare the working of evaporative and split-system air conditioners. Include reference to changes of state in your table.

5 Describe an example of a mixture that you would find in a kitchen that demonstrates the properties of a solid and a liquid. Suggest, in terms of particle theory, why it can do so.

6 Explain why liquefied petroleum gas (LPG) in cylinders can remain as a liquid well above the normal boiling point of the LPG.

3 Particle theory and properties of substances

Topic summary

The key concepts included in this topic are:

- Substances can be solids, liquids and gases based on their observable properties such as their shape and presence of a boundary.
- Substances can change state due to changes in temperature or pressure applied to the substance.
- All substances consist of particles.
- The properties of solids, liquids and gases can be explained by considering 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.

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, in terms of the attractions between particles, why sublimation occurs in some substances.

6 Some materials have the properties of more than one state of matter.
  a Explain why this can occur in some mixtures.
  b State two examples of mixtures that can be considered as solids or liquids.

7 Suggest a reason why the mass of a gas might be difficult to measure accurately using an electronic balance.

Apply

8 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.

9 Luke was investigating the rate of the evaporation of a liquid.
  a Predict how the evaporation rate of water in an open container would compare to the rate of evaporation in a closed container.
  b Explain the reasons for your prediction.
  c Suggest a method to measure the rate of evaporation of the liquid.
  d Name three other variables that would affect the rate of evaporation of the liquid.

10 Describe in detail what will happen to the particles in a liquid when it is cooled to its freezing point.

11 Caleb wanted to test the hypothesis that adding salt to water increases the boiling point of the water.
  a Write a prediction based on this hypothesis.
  b Describe how the student should ensure that the results from the experiment are valid.
  c Describe how the student should ensure that the results from the experiment are reliable.

Analyse

12 Amrita was investigating the amount of condensation 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 (60–80°C) into each of the 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 3 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	Petri dish around 10% covered in water
C	metal	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.

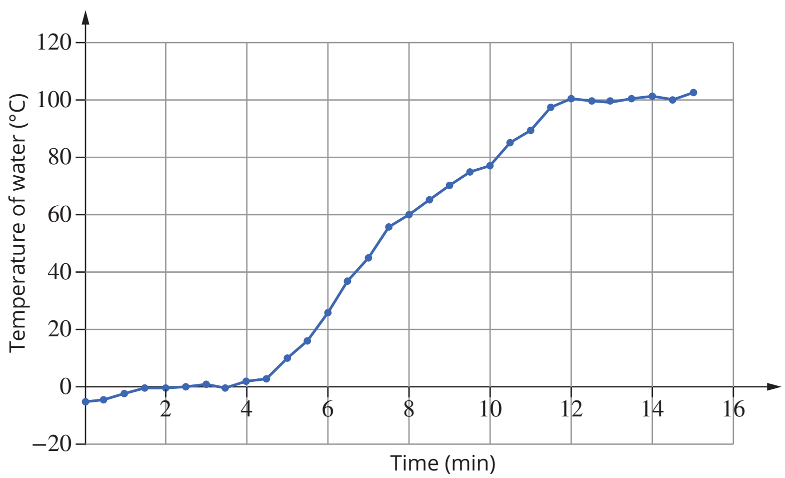
---

13 Mikalya was investigating the changes of state of water.

She started with approximately 100 grams 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 graph here.



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 and 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 Mikalya was carrying out this experiment in a town that was high above sea level.

Extension: Research and problem-solving

14 An example of evaporation is the drying of clothes after they have been washed. 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 the question, but some 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 than in 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 particular areas that you are confident in, and others where you are not so sure.

3 Glossary

analogy an event or situation that can be used to help describe or explain another similar event or situation

boiling a change of state in which a liquid is heated and changes to a gas within the liquid

boiling point the temperature at which a liquid boils

compressed reduced in volume (amount of space) or size by adding pressure

condensation a change of state in which a gas is cooled and forms a liquid

contract to decrease in size

dense containing a lot of matter in a small space

deposition the change in state from a gas to a solid, bypassing the liquid state

diffuse spread out

energy the ability to do work; can be in many forms, including heat, movement and electricity

evaluate to assess the quality or value of something

evaporation the change of state in which a liquid changes into a gas at the surface of the liquid

expand to increase in size

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

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

kinetic energy energy possessed by a moving object

line graph a 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 a substance made from two or more pure substances that have been combined and that can be separated to recover the original substances

model a representation that helps to describe or explain an object, event, system or idea

molten the liquid state of a substance that is normally a solid at room temperature

particle a tiny part of matter; include atoms and molecules

particle theory the theory that states that all matter consists of tiny particles that are constantly moving

phase another word for state (solid, liquid or gas)

prediction a statement that suggests what will happen in an experiment, normally based on a hypothesis

pressure the physical force exerted on an object or surface, measured as force per unit area

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

reversible can occur in both directions; for example, freezing is the reverse of melting

solid the state of matter that has a fixed shape and a fixed volume

state solid, liquid or gas (also plasma at temperatures above 600°C)

steam hot invisible gas given off as water is boiled (which often then forms a visible cloud of water droplets)

sublimation the change in state from a solid into a gas

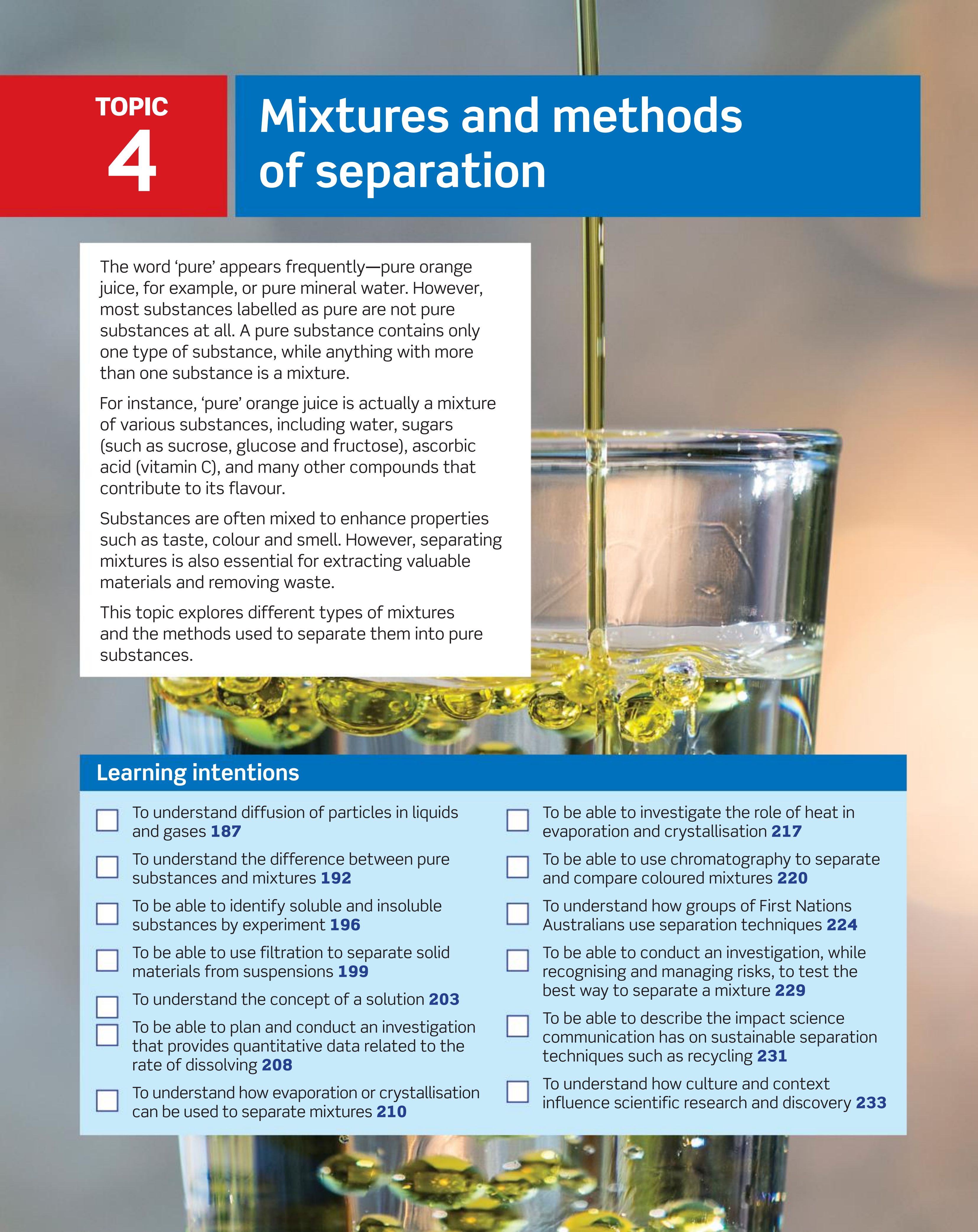
substance a material that has physical properties; a solid, liquid or gas

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; can be a pure gas, as in water vapour in the atmosphere, or a mixture of a gas and small droplets of liquid

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



TOPIC 4

Mixtures and methods of separation

The word ‘pure’ appears frequently—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.

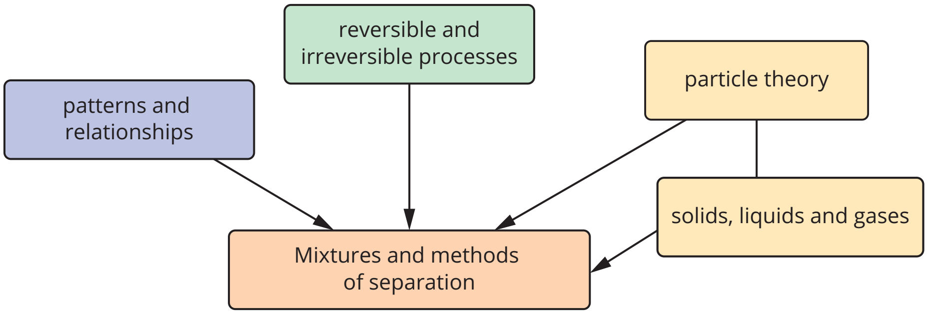
This topic explores different types of mixtures and the methods used to separate them into pure substances.

Learning intentions

- [ ] To understand diffusion of particles in liquids and gases **187**
- [ ] To understand the difference between pure substances and mixtures **192**
- [ ] To be able to identify soluble and insoluble substances by experiment **196**
- [ ] To be able to use filtration to separate solid materials from suspensions **199**
- [ ] To understand the concept of a solution **203**
- [ ] To be able to plan and conduct an investigation that provides quantitative data related to the rate of dissolving **208**
- [ ] To understand how evaporation or crystallisation can be used to separate mixtures **210**
- [ ] To be able to investigate the role of heat in evaporation and crystallisation **217**
- [ ] To be able to use chromatography to separate and compare coloured mixtures **220**
- [ ] To understand how groups of First Nations Australians use separation techniques **224**
- [ ] To be able to conduct an investigation, while recognising and managing risks, to test the best way to separate a mixture **229**
- [ ] To be able to describe the impact science communication has on sustainable separation techniques such as recycling **231**
- [ ] To understand how culture and context influence scientific research and discovery **233**

4 Mixtures and methods of separation

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 the information to determine if material X is a solid, liquid or gas.

Solids, liquid 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 Backyard firepits have become very popular in Victoria, allowing people to enjoy being outdoors even on chilly evenings. The fire produces heat for warmth and cooking marshmallows. Wood and oxygen react together to form charcoal, gases, steam and ashes. Explain why this reaction is an irreversible process.

7 Classify the following processes as reversible or irreversible.

a boiling water

b baking a cake

c melting wax

4.1 Diffusion and particle theory

Lesson overview

Particles in liquids and gases can move freely. When one liquid is added into another, the particles from both liquids can mix as the newly added liquid spreads out in the other liquid (Figure 4.1.1). This process is called diffusion.

In a gas, particles can move in all directions, so any gas will spread out into the surrounding air. You may not be able to see this occurring, but you can often smell the gas or vapour as it moves through the air.

In this lesson, you will learn about how to identify when diffusion is occurring in liquids and gases, and to explain what is happening in terms of the movement of particles.

FIGURE 4.1.1 Blue food colouring spreads out into water.

Learning intention

To understand diffusion of particles in liquids and gases

Success criteria

SC 1: I can use observations to show that diffusion has taken place.

SC 2: I can describe diffusion in terms of the behaviour of particles.

SC 3: I can explain why diffusion occurs more quickly in gases than liquids.

KEY TERM

diffusion a process in which two liquids or two gases mix due to the motion of their particles

SC 1 I can use observations to show that diffusion has taken place

Diffusion is the spreading out of a liquid or gas into another liquid or gas. It can be identified if one of the properties (e.g. colour, smell) of one of the substances can be observed in the substance that it is mixing with.

Diffusion of liquids

The diffusion of coloured liquids is easy to observe (Figure 4.1.2).

If the two liquids are colourless, it is more challenging to identify that diffusion has taken place. However, as the liquids mix, properties such as taste and density may change, which can indicate that diffusion has occurred.

FIGURE 4.1.2 The colour spreads through water as the orange liquid diffuses.

Liquids that do not mix

If liquids do not mix (e.g. water and oil), they cannot diffuse into each other (Figure 4.1.3). They can be made to mix, but when left for some time, the two liquids will separate.

FIGURE 4.1.3 The particles of oil and water do not mix.

FIGURE 4.1.4 It might look like the mud has diffused, but the particles have not properly mixed.

Solids and powders in liquids

If a solid is mixed with a liquid, but stays as a solid (even in the form of powder), this is not diffusion. The particles of each substance have not properly mixed. If left for some time, it is likely that the solid will simply sink to the bottom of the liquid or float to the top (Figure 4.1.4).

Diffusion of gases

The diffusion of gases is difficult to observe as most gases are colourless. However, there are coloured gases in which diffusion can be observed (Figure 4.1.5).

The easiest way to detect gas diffusion is through smell. Many everyday situations rely on this, such as fragrances and food. A fragrance is a pleasant or sweet smell, and is detected when vapours from a flower or perfume diffuse through the air and reach the nose (Figure 4.1.6).

Food vapours also spread by diffusion. The nose detects these smells when particles from the food reach its sensing cells. Cooking on a barbecue, frying onions, and baking biscuits are common examples (Figure 4.1.7).

FIGURE 4.1.5 Iodine forms a purple-coloured gas. Diffusion of the purple gas can be observed outside the flask.

FIGURE 4.1.6 You can smell perfume when its vapour diffuses through the air.

FIGURE 4.1.7 You can smell a barbecue when the particles from the cooking food diffuse through the air.

Many gases, however, do not have an odour and are colourless. These gases can be fatal if toxic or can cause asphyxiation (where oxygen levels in the air are so low, the body becomes deficient in oxygen and the person becomes unconscious). Until about 50 years ago, canaries were used in coal mining as an early warning system for the diffusion of odourless gases such as carbon monoxide and methane. Signs of distress in the bird indicated to the miners that conditions were unsafe. Nowadays, due to advanced technology, gas sensors are able to detect and measure odourless, toxic and colourless gases in the air (Figure 4.1.8).

FIGURE 4.1.8 This detector is testing for levels of the toxic gas hydrogen sulfide (H_2S).

SC 1 CHECK YOUR UNDERSTANDING

Explain how you know that diffusion has taken place when you smell perfume from across the room.

SC 2 I can describe diffusion in terms of the behaviour of particles

Particle theory explains that all substances are made up of particles, and that these particles are moving in some way. Figure 4.1.9 shows a representation of particles in a liquid and Figure 4.1.10 shows a representation of particles in a gas.

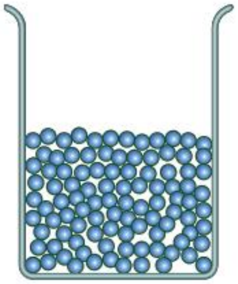


FIGURE 4.1.9 A representation of particles in a liquid

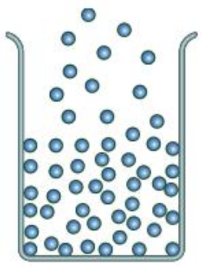


FIGURE 4.1.10 A representation of particles in a gas

Particles in liquids

Table 4.1.1 summarises how particles in liquids behave.

TABLE 4.1.1 The movement, attraction, compressibility and shape of liquids

Movement	Particles move slowly past each other in random directions.
Attractions	There are fairly strong attractions between particles, keeping them close together but not fixed in the same positions.
Compressibility	Liquids have a fixed volume because particles are close together with no space between them, so they cannot be compressed.
Shape	Liquids do not have a fixed shape and can flow because the particles are not in fixed positions.

Particles in gases

Table 4.1.2 summarises how particles in gases behave.

TABLE 4.1.2 The movement, attraction, compressibility and shape of gases

Movement	Particles move in all directions at different speeds, some very quickly.
Attractions	There are very weak attractions between particles.
Compressibility	Particles are spread out with huge spaces between particles, so gases are easily compressed.
Shape	Gases do not have a fixed shape or volume.

Mixing of particles

The particles in liquids are moving randomly in all directions. When one liquid is added to another, the particles of the added liquid will spread out into the other liquid. This is called diffusion.

Figure 4.1.11 demonstrates the (red) particles of one liquid mixing with the (blue) particles of another liquid.

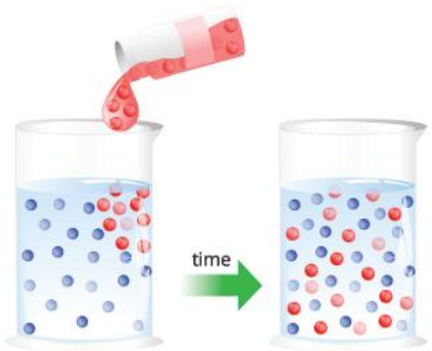


FIGURE 4.1.11 The red particles of one liquid mix with the blue particles of another liquid by diffusion.

When two gases mix, it is a similar situation. Figure 4.1.12 shows particles of gas 1 (in blue) diffusing through the hole in the container into gas 2 (in yellow) and gas 2 also diffusing into gas 1. If this situation was left for some time, the gases will be completely mixed.

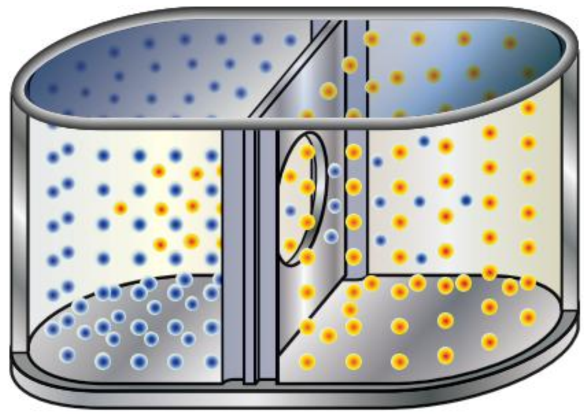


FIGURE 4.1.12 The blue particles of gas 1 and yellow particles of gas 2 are mixing by diffusion.

After a while, the particles in the mixture that is formed will be completely mixed. When this happens, the movement of the particles does not stop, there is just no overall net movement.

SC 2 CHECK YOUR UNDERSTANDING

Explain why food colouring spreads out when added to water.

SC 3 I can explain why diffusion occurs more quickly in gases than liquids

Particle theory for gases

Particles in a gas are moving quickly in all directions. There are also huge spaces between particles in a gas. For example, at 25°C, particles of the gases in the air take up only 0.1% of the volume of the air. It is very difficult to imagine the real sizes of particles (atoms or molecules) and the distances between them. However, if you imagine a particle of air to be about the size of an M&M, the average distance to the next particle would be around 10 cm. That leaves a lot of space. And remember that this space is real space—there is literally nothing there!

Therefore, if one gas is added to another gas, nothing is stopping the particles of the two gases from mixing. Some of the particles of one gas move into the spaces between the particles of the other gas and at the same time, the particles of the other gas move into the spaces of the first gas.

Eventually, the gases will be completely mixed. The faster the particles are moving, the quicker they will mix, so gases will diffuse more quickly at higher temperatures.

Particle theory for liquids

Compared to gases, the particles in liquids have hardly any space between them.

There are also attractions between the particles in a liquid. Therefore, for particles of a liquid to diffuse into another liquid, the attractions between all particles must be reduced so that the particles can fit in between each other.

Imagine a group of people standing very close together. Then another group of people comes towards them and this group tries to mix with the first group. That's a bit like two liquids diffusing into each other!

Speed of diffusion in liquids and gases

Because the particles in a gas are well spaced out and moving fast, diffusion in gases will happen much more quickly than in a liquid.

When diffusion occurs, liquid or gas particles move from a region of high concentration to one of low concentration. Diffusion does not rely on the movement of air (e.g. wind) or the liquid (e.g. stirring). Diffusion occurs by particles randomly moving and these particles collide with other particles present; therefore, diffusion takes time. If the temperature has increased, the particles move more quickly, increasing the number of collisions. If the number of collisions increases, then diffusion happens faster.

SC 3 CHECK YOUR UNDERSTANDING

Predict how the diffusion of a smell would change if the temperature of the air increases.

Lesson review

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

1 Explain how you can tell that diffusion has occurred in a gas, using air freshener as an example.

2 Apply the concept of diffusion to explain why you can smell onions on a barbecue, even though you cannot see the barbecue.

3 Compare the diffusion rates of a gas and a liquid and describe the reasons for the difference.

4 Apply your understanding of diffusion to explain what would happen if you placed a sugar cube in a cup of hot tea.

5 A student observes the diffusion of a perfume in a room and the diffusion of food colouring in water.

- a Describe the diffusion process in both scenarios.
- b Explain why the perfume spreads faster in the room than the food colouring in water.
- c Predict what would happen if both experiments were conducted at a higher temperature.
- d Compare the diffusion rates in both scenarios and write your conclusion about the impact of temperature.

4.2 Pure substances and mixtures

Learning intention

To understand the difference between pure substances and mixtures

Success criteria

SC 1: I can list examples of pure substances and mixtures.

SC 2: I can classify some mixtures as solutions or suspensions by observation.

SC 3: I can describe the differences between pure substances, suspensions and solutions in terms of particles.

Lesson overview

Substances can be classified as either pure substances or mixtures. While a few everyday substances, such as table salt and purified water, are pure, most materials are mixtures.

In this lesson, you will learn about the difference between pure substances and mixtures (Figure 4.2.1). You will also learn about solutions and suspensions: two particular examples of mixtures. Finally, you will learn how to describe pure substances, solutions and suspensions, in terms of the particles involved.

FIGURE 4.2.1 How can you tell if this is a pure substance or a mixture?

SC 1 I can list examples of pure substances and mixtures

Examples of pure substances and mixtures

You may remember that scientists use the **particle model** to understand the behaviour and properties of solids, liquids and gases. You can also use this model to explain the difference between a pure substance and a mixture (Figure 4.2.2).

A **pure substance** is made of only one type of **substance**. If you were to draw a diagram showing the **particles**, they would all be the same. For example, a pure sample of sugar contains only sugar particles. A pure sample of water contains only water particles. A **mixture** is a combination of two or more substances, which can be separated into the pure substances.

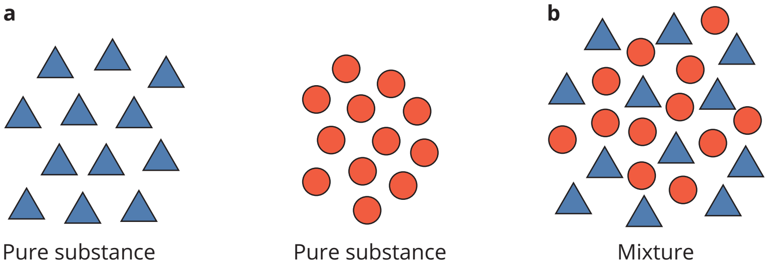


FIGURE 4.2.2 A representation of the particles in two pure substances (blue triangles and red circles) and a mixture of both

KEY TERMS

particle model a representation used to help describe and explain the behaviour of particles in solids, liquids and gases
pure substance a substance that is made up of only one type of material
substance a material that has physical properties; a solid, liquid or gas
particle a tiny part of matter; includes atoms and molecules
mixture a combination of two or more pure substances that can be separated to recover the pure substances

Comparing pure substances and mixtures

Pure substances only contain one type of substance. Table 4.2.1 shows some examples of pure substances.

TABLE 4.2.1 Examples of pure substances

Pure water contains only particles of water.

Sucrose is a pure type of sugar.

The helium in these balloons is a pure substance.

Table 4.2.2 shows everyday examples of mixtures. Other examples are milk, concrete, bronze and most medicines.

TABLE 4.2.2 Examples of mixtures

Soft drinks contain a mixture of water, sugar, flavouring and carbon dioxide gas for the bubbles.

Salad contains a mixture of lettuce, tomato, onion, cucumber and other ingredients.

Petrol is a mixture of many different substances.

Scifile

Tap water

Tap water is not pure water. Tap water contains dissolved gases and other substances. Therefore, tap water is a mixture. Air is also a mixture of gases, including nitrogen, oxygen, carbon dioxide, argon and other gases.

SC 1 CHECK YOUR UNDERSTANDING

Identify whether a bowl of cereal with milk is a pure substance or a mixture.

SC 2 I can classify some mixtures as solutions or suspensions by observation

There are many different types of mixtures. It is possible to have a mixture of gases (e.g. air), or liquids (e.g. cordial), or solids (e.g. a cake mix). It is also possible to have mixtures of two different states of matter—such as the bubbles of gas in a bottle of soda water.

Two common types of mixtures are **solutions** and **suspensions**.

KEY TERMS

solution a mixture in which one substance is dissolved in another

suspension a mixture in which a substance will not dissolve in another and separates out if left to stand

KEY TERMS

dissolve to mix completely with liquid
solvent a substance that dissolves another substance
solute a substance that dissolves to make a solution when it is mixed into another substance
soluble able to dissolve in a particular solvent
insoluble unable to dissolve in a particular solvent

FIGURE 4.2.3 When dissolved in water, copper sulfate makes a clear, bright blue solution.

FIGURE 4.2.4 Orange juice with pulp is a suspension—this is why it needs to be shaken before pouring.

Solutions

When salt is stirred into water, it seems to disappear. However, you know it is still there because the water tastes salty. So, where has it gone? The salt has broken down into tiny particles that spread throughout the water particles. These particles are so small, they can no longer be seen.

When this happens, the salt has **dissolved** in the water. The water is an example of a **solvent**. This salt and water mixture is now known as a solution, and the salt is an example of a **solute**. It can also be described as a **soluble** substance. A substance that does not dissolve is known as **insoluble**. An example of an insoluble substance would be sand or flour.

One way to recognise a solution is to check whether you can see through it. Solutions are transparent (see-through), and you can describe them as being clear. Colourless and clear are not the same. Clear means you can see through it. Colourless means it is not coloured. A solution can be clear and colourless, like tap water. Other solutions may be clear and coloured, like copper sulfate solution (Figure 4.2.3).

Suspensions

Sometimes you may have a mixture that is a liquid, but you cannot see through it. This type of mixture is called a suspension. Think of a bottle of orange juice—when you shake it up, it is opaque (not clear). Sometimes, if it is left to settle, then there may be a clear solution at the top, while all the solid pulp sinks to the bottom.

In a suspension, the particles of the substance that is added to the water do not become small enough to disappear. Instead, the suspension reflects light and appears cloudy. The larger, solid pieces are not dissolved; instead they are suspended throughout the mixture. One example of a suspension is orange juice (Figure 4.2.4).

SC 2 CHECK YOUR UNDERSTANDING

Explain how you can use observations to tell if a mixture is a solution.

SC 3 I can describe the differences between pure substances, suspensions and solutions in terms of particles

One of the ways that scientists understand the world is by picturing what is happening with the particles involved. In a pure substance, the particles will all be the same, whether the substance is a solid, liquid or gas (Figure 4.2.5).

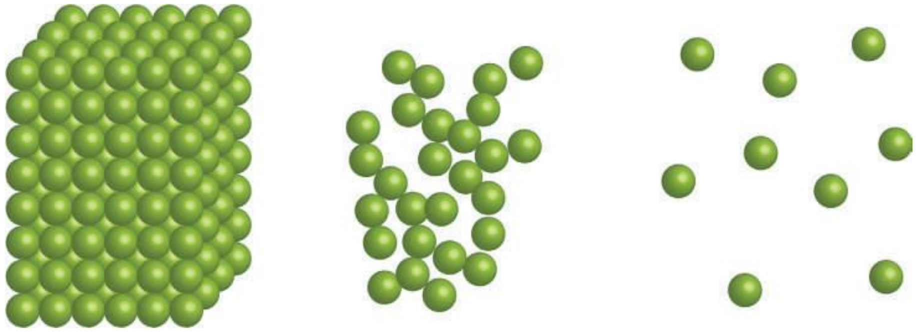


FIGURE 4.2.5 A representation of the particles in pure samples of a solid, liquid and gas

Suspensions and solutions

Suspensions and solutions are both mixtures, and so contain more than one type of particle (Figure 4.2.6). In a suspension, the solid particles that are suspended within a liquid are made from many smaller particles. An example is chalk powder that has been mixed into water. If a suspension is left to settle, you will often be able to see these larger particles collecting at the bottom of the container. Suspensions appear cloudy or milky.

With solutions, the substance added to the solvent breaks down into particles so small that they can no longer be seen. They are still there, in between the water particles. A solution can be coloured or colourless, but it will always be clear. If a solution is left for a long period of time, the substances remain mixed and will not separate.

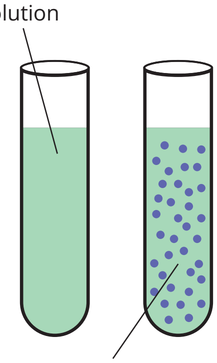


FIGURE 4.2.6 The particles in the solution on the left are too small to be seen, so the solution is clear. The particles in the suspension on the right are larger and prevent light passing through the mixture.

SC 3 CHECK YOUR UNDERSTANDING

Describe the particle arrangement in a suspension.

Lesson review

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

1 Choose whether ice-cream is a pure substance or a mixture and explain why.

2 Explain how you can distinguish between a solution and a suspension by observation.

3 A student mixes flour into some water in beaker A and sugar into some water in beaker B.

- **a** Describe the appearance of each mixture.
- **b** Identify which mixture is a solution and which is a suspension.
- **c** Explain the reasoning behind your identification.

4 Apply your understanding of solutions and suspensions to describe the particle behaviour in a mixture of oil and water when it is shaken and left to stand.

4.3 Soluble and insoluble substances

Learning intention

To be able to identify soluble and insoluble substances by experiment

Success criteria

SC 1: I can use prior knowledge to predict whether a range of substances will dissolve in different solvents.

SC 2: I can record observations about the solubility of different substances.

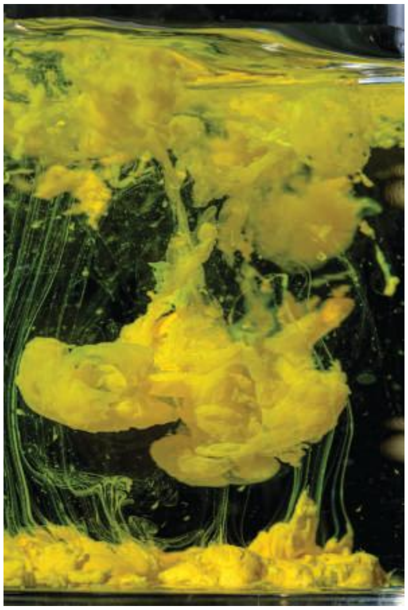


FIGURE 4.3.1 Lead chromate, the yellow substance, is insoluble in water.

GO TO
Toolkit section 1.3, Hypotheses and predictions

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 4.3.1), 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 two different solvents, water and kerosene.

Background

Substances that dissolve in 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, contain lumps, or form layers where the two substances have not dissolved together.

Aim

To investigate what substances will dissolve in water and kerosene

Prediction

Using your previous observations from everyday life, predict which substances will dissolve before you carry out the tests. Write down your predictions.

Materials

- $\frac{1}{2}$ small spatula copper carbonate ($CuCO_3$)
- $\frac{1}{2}$ small spatula copper sulfate ($CuSO_4$)
- $\frac{1}{2}$ small spatula table salt (NaCl)
- cooking oil in dropping bottles
- 6 mL kerosene
- 6 medium-sized test tubes with stoppers to fit
- test-tube rack
- marking pen or sticky labels
- spatula

SAFETY NOTES

- Copper sulfate and copper carbonate are toxic so do not touch, sniff or taste them.
- Do not wash copper sulfate, copper carbonate or kerosene down the sink.
- Kerosene is flammable and should be kept away from naked flames.
- Always wear safety glasses and rubber gloves to avoid contact of chemicals with your skin and eyes.
- Avoid inhaling fumes by doing the activity in a well-ventilated area.
- Keep kerosene bottles and test tubes containing kerosene stoppered whenever possible, to prevent fumes being released into the room.

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

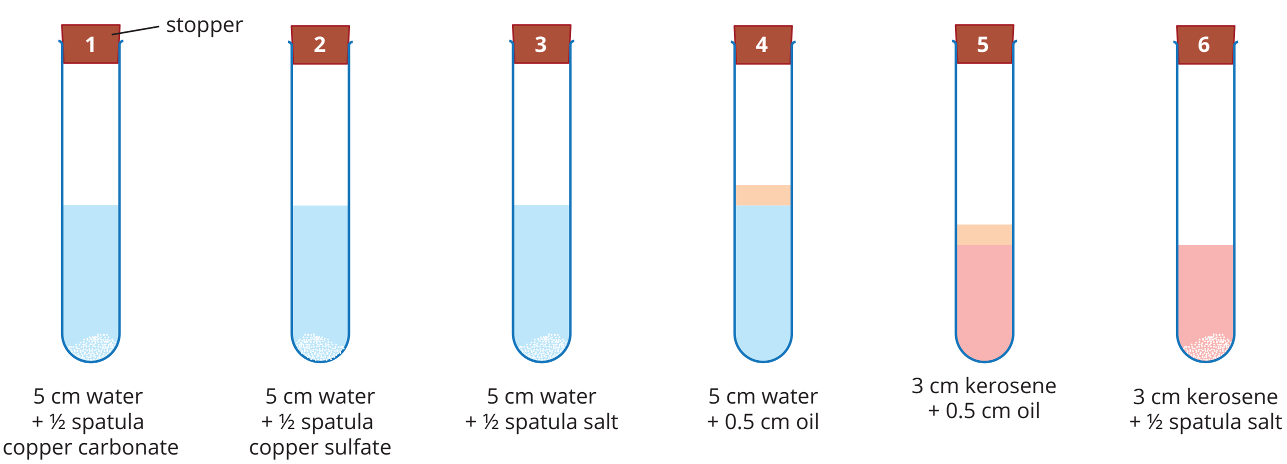
1 Review the results table on the next page.

2 Place the test tubes in the rack. Use the marking pen or sticky labels to number them 1 to 6.

3 Add tap water to approximately 5 cm depth in test tubes 1–4. Pour kerosene to a depth of 3 cm into test tubes 5 and 6.

4 Complete the prediction column for each test tube in the results table.

5 Add very small amounts of the different solutes to the different test tubes as shown in the diagram.



6 Place a stopper in each test tube. Shake each of the test tubes for about 1 minute. Place all the test tubes in the test-tube rack and record what you see.

7 Do not tip anything down the sink. Return all test tubes and liquids to your teacher.

Results

Test tube number	Solvent	Solute	Prediction: soluble, insoluble or unsure?	Observations	Substance soluble or insoluble?
1	water	copper carbonate			
2	water	copper sulfate			
3	water	salt			
4	water	oil			
5	kerosene	oil			
6	kerosene	salt			

Conclusion

Write your conclusion by answering the following questions.

1 Describe the observations that helped you to decide whether a solute dissolved to form a solution.

2 In which test tubes did a solution form?

3 Name the substances that were insoluble in water.

4 Identify the substance that is a solvent for salt but not for oil.

GO TO
Toolkit section 4.1, Evaluating investigations

Evaluation

Evaluate your practical investigation by answering the following questions.

1 Comment on the accuracy of your predictions.

2 Describe two possible improvements to the method for the experiment.

4.4 Filtering

Introduction

Filtering is used in many situations, including water treatment, making drinks such as tea and coffee, and washing machines. Filters are also used to separate substances from air, such as in air conditioners and face masks.

In the laboratory, there is specialist equipment, such as filter funnels, conical flasks and filter paper, that can be used for this process (Figure 4.4.1).

In this practical investigation, you will compare two ways of using filter paper to evaluate which one is the most effective.

Background

When a liquid mixture contains an insoluble substance, it can be described as a suspension. Filtering can be used to separate out the insoluble substance.

Very small particles can pass through the gaps in the filter paper, but the larger pieces of the insoluble substance are trapped by the paper.

Aim

To compare conical and fluted filter papers

Hypothesis

Which filters faster—a conical filter paper or a fluted filter paper? Write a hypothesis.

Prediction

Predict which type of filter paper will complete the filtering of sand and copper carbonate in a shorter time. Write a prediction and give a reason for your prediction.

Materials

- 2 spatulas of copper carbonate ($CuCO_3$)
- 2 spatulas of sand
- 1 spatula
- 2 filter funnels and 4 pieces of filter paper
- 4 × 100 mL conical flasks (or 4 × 100 mL beakers), plus retort stand, bosshead and clamp—see Skillbuilder: Setting up a filter funnel
- 2 stirring rods
- 2 stopwatches or timers

Learning intention

To be able to use filtration to separate solid materials from suspensions

Success criteria

SC 1: I can use filter paper in two different ways to separate solid materials from 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.

FIGURE 4.4.1 A filter paper is being used to filter solid from a suspension

HINT

Make sure your hypothesis suggests a link or relationship between the independent variable (the variable that will be changed) and the dependent variable (the variable that will measured).

GO TO

Toolkit section 1.3, Hypotheses and predictions

SAFETY NOTE

- Copper carbonate is toxic, so do not touch, sniff or taste it.

Assessment of risk

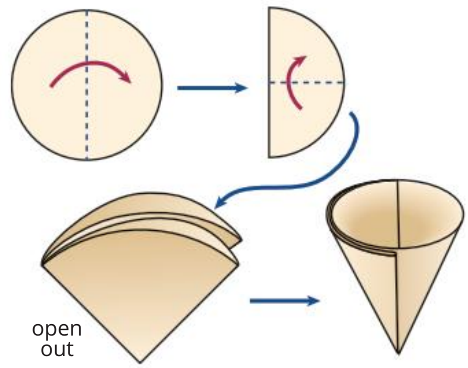
Make sure you are aware of the risks of this practical investigation and have considered how safety can be improved before carrying out this activity.

SkillBuilder

Folding a filter paper

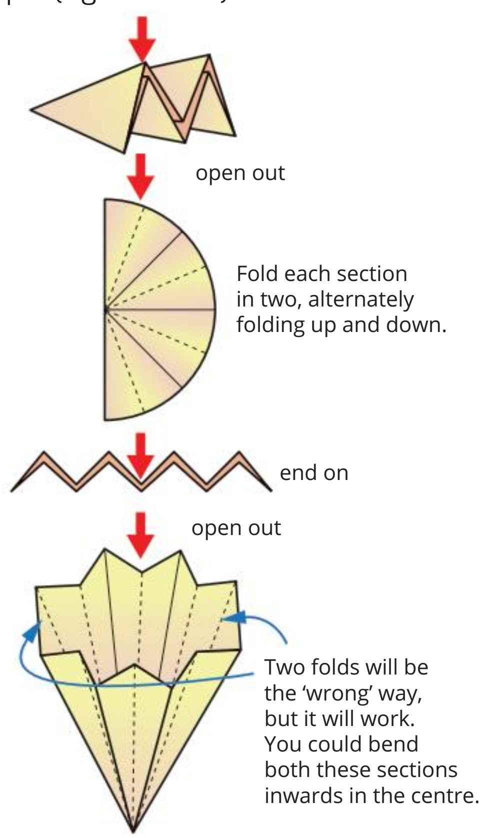
Method for conical shape

1. Fold the filter paper in half.
2. Then fold it in half again.
3. Open out one 'layer' of the folded paper.
4. Bend the paper into a cone (Figure 4.4.2a).



Method for fluted shape

1. Fold the filter paper in half.
2. Fold the folded paper again into four sections as shown in the first step in the diagram, alternately folding up and down.
3. Open out back to the half folded paper and then fold each of the four sections into two, alternately folding up and down.
4. Open out the paper (Figure 4.4.2b).



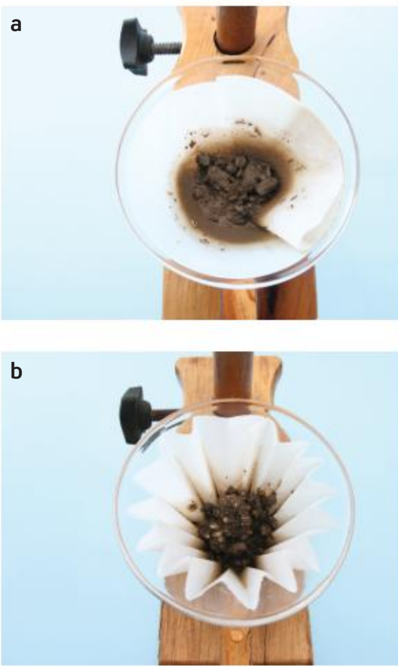


FIGURE 4.4.2 **(a)** The filter paper folded into a conical shape and **(b)** the filter paper folded into a fluted shape

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 Figure 4.4.3, or you can use a filter funnel stand, or place the filter funnel in conical flask.
3. Carefully pour the mixture to be separated into the filter funnel. The liquid that passes through the filter is called the **filtrate**. The solid that is trapped in the filter paper is called the **residue**.
4. Do not let the mixture reach the top of the filter paper.

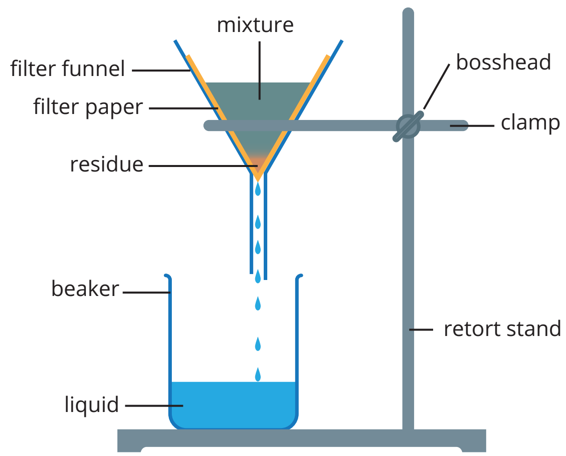


FIGURE 4.4.3 The set up of a filter funnel

KEY TERMS

filtrate the liquid that passes through the filter paper

residue the solid left in the filter paper after filtration

Method

1. Set up two filter funnels in two clamps or filter stands. 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 a funnel.
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 step 2 for another beaker.
4. Pour some of the contents of one beaker into the conical filter paper. Start the timer as soon as the water goes into the conical filter paper. Do not let the water level reach the top of the filter paper.
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.
6. Keep adding the sand and water mixture to each filter paper until all the liquid has been filtered. Stop the timer when no more liquid is left. Leave any remaining sand in the beaker.

HINTS

Do not let the liquid in the filter paper get too close to the top of the paper.

Be careful not to tear or poke any holes in the filter paper.

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 solute 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:s)	Appearance of filtrate
conical	sand		
fluted	sand		
conical	copper carbonate		
fluted	copper carbonate		

Conclusion

Write your conclusion by answering the following questions.

1 Assess how accurate your prediction was, and therefore whether your hypothesis was supported or not.

2 Propose a reason why one folding method was better than the other.

3 Describe, in terms of particles, how the filter papers were able to separate the two mixtures.

4.5 Solutions

Lesson overview

Solutions are formed when one substance, the solute, dissolves in a solvent. In a solution, the substances have completely mixed, and the properties of the mixture are the same throughout (Figure 4.5.1). 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.

Gases can also form solutions. If two or more gases mix completely together, they can be described as gaseous solutions. An example is the gas used for barbeques, which is a mixture of propane and butane gas.

In this lesson, you will learn about more examples of solutions, explore the use of a range of solvents and consider how the concentration of a solution can affect its properties and use.

Learning intention

To understand the concept of a solution

Success criteria

SC 1: I can describe examples of natural and manufactured liquid and gaseous solutions.

SC 2: I can describe the use of different solvents in a range of solutions.

SC 3: I can explain the concept of concentration of a solution in terms of particles.

SC 1 I can describe examples of natural and manufactured liquid and gaseous solutions

Examples of liquid solutions

Most solutions in everyday lives 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%).

FIGURE 4.5.1 The chemicals here are all solutions.

Solutions in human bodies

Sweat is a solution of small amounts of ammonia, urea, salts and sugar dissolved in water (Figure 4.5.2). The **evaporation** of sweat from the skin cools your body. When the water from sweat evaporates, you can often see the white traces of salt on clothing or skin.

Urine is another solution, which contains some of the same chemicals as sweat. However, the additional waste products in urine, such as uric acid, give this solution different properties to sweat, such as colour and smell.

KEY TERMS

aqueous solution a solution in which water is the solvent

evaporation the change of state in which a liquid changes into a gas at the surface of the liquid

FIGURE 4.5.2 Sweat is a solution of small amounts of chemicals dissolved in water.

Other natural liquid solutions

There are many solutions in the environment. Seawater contains salt, but it also contains many other substances. However, the concentrations of these substances may be very low. For example, 30 Olympic-size swimming pools of seawater would only contain 1 gram of gold!

FIGURE 4.5.3 Sports drinks are solutions that can quickly replace water, salts and sugar in the body.

Manufactured (artificial) solutions

Many everyday drinks are solutions. These include clear apple juice, black tea or coffee, soft drinks such as cola and soda water.

Isotonic sports drinks (Figure 4.5.3) 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.

KEY TERMS

diffuse spread out
gaseous in the form of a gas

Examples of gaseous solutions

When gases mix, they will always form a 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 spread (**diffuse**) into each other. Solutions of gases are like liquid solutions in that the particles of the substances are completely mixed.

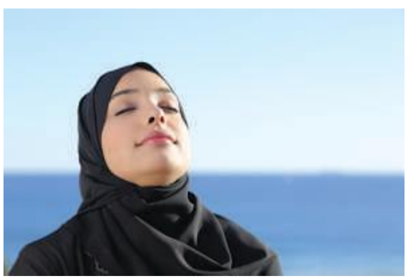


FIGURE 4.5.4 The air that you breathe is a solution containing many gases.

Natural gaseous solutions

Air is a **gaseous** solution (Figure 4.5.4). The air inhaled consists of approximately 78% nitrogen, 21% oxygen, 0.04% carbon dioxide and around 1% other gases. As air passes through the lungs, the oxygen concentration decreases to 17%, while the carbon dioxide concentration rises to about 4%.

Natural gas is another example of a solution of gases. It contains mainly methane, with other gases, including butane and propane and is found in the earth close to deposits of crude oil.

FIGURE 4.5.5 LPG is often a solution of gases that has been pressurised to convert into a liquid form for storage.

Manufactured (artificial) gaseous solutions

Solutions display a combination of the properties of the components of the solution. To produce the required properties for a particular use, gases are often mixed. For example, liquefied petroleum gas, LPG, (Figure 4.5.5), which is used for barbecues, gas stoves and heating, is often a mixture of butane and propane. The gas is pressurised so that it can be stored in liquid form.

However, this varies across the world. In many parts of Australia, LPG is almost all propane, in Western Australia, LPG tends to contain a higher concentration of butane (up to 50%), in New Zealand the mix is 60% propane and 40% butane, but 70% propane and 30% butane in winter because propane evaporates more easily into a gas than butane at lower temperatures.

SCIENCE IN SOCIETY

Making water safe for drinking

In Australia, water treatment plants use the principles of solubility to ensure clean and safe drinking water. Soluble chemicals and minerals can be removed from water through various treatment processes. For example, chlorine is often added to water because it is soluble and helps kill harmful bacteria and viruses. However, insoluble substances such as dirt and debris need to be filtered out. This is done through processes like sedimentation (settling of particles) and filtration, where the insoluble particles are separated from the water.

Figure 4.5.6 is a photo of the drinking water treatment plant north-east of Melbourne, which supplies one-quarter of Melbourne's drinking water. Winneke Water Treatment Plant is run by Melbourne Water. Water is collected from Sugarloaf Reservoir and processed through large ponds, where soluble and insoluble substances in the water are removed by chemical processes, sedimentation and filtration. The final steps, before the water is pumped to taps, are to disinfect the water using chlorine and add fluoride to protect teeth.

Understanding solubility helps water treatment professionals, such as Melbourne Water, make informed decisions about how to purify water and ensure it is safe for consumption.

FIGURE 4.5.6 Winneke Water Treatment Plant located north-east of Melbourne

SC 1 CHECK YOUR UNDERSTANDING

Explain why fizzy drinks are considered manufactured (artificial) solutions.

SC 2 I can describe the use of different solvents in a range of solutions

Solvents

The solvent in a solution is the substance into which the other substance(s) dissolve. Water is the most common solvent, but not all substances dissolve in water, so often other solvents need to be used (Figure 4.5.7).

Non-aqueous solvents

Imagine trying to remove an oil-based substance such as paint from a surface. Because oil does not mix with water, water will not remove the substance, but a solvent such as turpentine can dissolve the oil to make a solution that can then be washed away. Table 4.5.1 provides three other common products that contain non-aqueous solvents.

FIGURE 4.5.7 These substances are all solvents that can be used for household cleaning.

TABLE 4.5.1 Three examples of common products using non-aqueous solvents

Example	Nail polish remover	Iodine (used as disinfectant)	Glue
Solvent	acetone (also called propanone)	alcohol	ethyl acetate (because it is relatively safe)
Other information	Nail polish remover will also contain materials such as lanolin and castor oil dissolved in the acetone to improve the effectiveness, and the smell of the product.	These alcohol solutions are sometimes called tincture of iodine.	Non-aqueous solvents are often used in glues because they evaporate quickly, which means that the glue will dry faster than water-based adhesives.

SC 2 CHECK YOUR UNDERSTANDING

Explain why alcohol is used as a solvent for iodine.

SC 3 I can explain the concept of concentration of a solution in terms of particles

The **concentration** of a solution is a measure of how much dissolved solute there is compared to the amount of the solution. The amounts can be measured in terms of volume or mass and are often listed as a percentage (Figure 4.5.8). For example, the concentration of sugar in some cola drinks is 16% of the mass of the drink. That's 38 g in one can. Urine normally has a sugar (in the form of glucose) concentration of only 0.001%. If the concentration of glucose is higher or lower than normal, it could be a sign of a health problem such as diabetes.

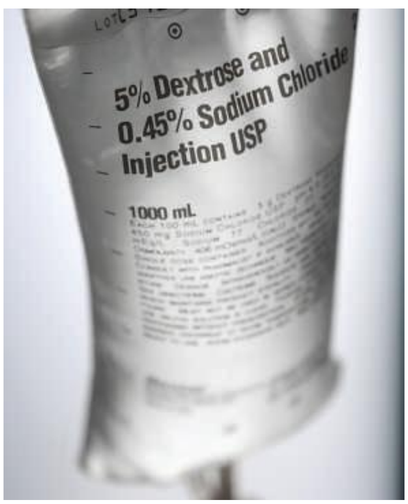


FIGURE 4.5.8 This hospital drip contains 5% dextrose (a type of sugar) and 0.45% sodium chloride (salt).

KEY TERMS

dilute a solution that has a small amount of dissolved solute compared to the amount of solution

concentrated a solution that has a large amount of dissolved solute compared to the amount of solution

Concentrations and particles

The concentration of a solution depends on how many particles of the solute can completely mix with the particles of the solvent (Figure 4.5.9).

If there are only a few particles of the solute, then the solution is **dilute** (it has a low concentration).

When there are many solute particles, the solution is **concentrated** (it has a high concentration).

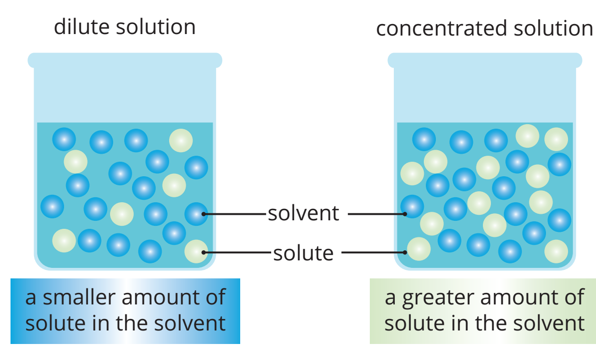


FIGURE 4.5.9 A representation of a dilute solution and a concentrated solution

Heat and particles in solutions

When substances heat up, the average energy of the particles in the substance increases. This means that if a solution is heated, the particles of both the solvent and the solute will move faster. This may affect how many particles of the solute can mix (dissolve into) the particles of the solvent. Normally this means that the solute can dissolve faster and that more solute will dissolve. For example, the amount of sugar dissolved in water increases as the water is heated (Figure 4.5.10). However, this is not always the case since the increased temperature affects both the solute and the solvent. In some cases, the combined effect is to reduce the number of particles of the solute that can be dissolved.

FIGURE 4.5.10 Heating water allows more sugar to be dissolved, and the concentration of the sugar solution will increase.

KEY TERM

saturated solution a solution that contains as much dissolved solute as possible

FIGURE 4.5.11 This is a saturated salt solution; there is undissolved solute visible because the solvent has dissolved as many particles of solute as is possible.

Saturated solutions

At some point, no more particles of the solute will be able to dissolve into the solvent. The solvent can be considered as 'full'. At this point, the mixture is described as a **saturated solution** (Figure 4.5.11).

SC 3 CHECK YOUR UNDERSTANDING

Describe how you would increase the concentration of a saltwater solution.

Lesson review

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

1 Explain the difference between natural and manufactured (artificial) solutions.

2 Describe the role of acetone as a solvent in nail polish remover.

3 Explain how to increase the concentration of a solution.

4 Compare the concentration of two solutions: one with 10 g of salt in 100 mL of water and the other with 5 g of salt in 100 mL of water. Determine which solution is more concentrated.

5 Describe an example of a natural gaseous solution.

4.6 Investigating the rate of dissolving

Learning intention

To be able to plan and conduct an investigation that provides quantitative data related to the rate of dissolving

Success criteria

SC 1: I can identify factors that will affect the rate at which a solute dissolves.

SC 2: I can plan and conduct a valid investigation that tests a hypothesis based on the rate of dissolving.

SC 3: I can develop a conclusion that relates to a hypothesis.

Introduction

When substances dissolve, particles in the solute need to separate and spread out into the solvent (Figure 4.6.1). 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 of 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.

FIGURE 4.6.1 A substance that dissolves in a solvent is called a solute.

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 related to the temperature of the water?

Hypothesis

Name the independent variable and the dependent variable for this experiment.

Then write a hypothesis for your investigation.

GO TO
Toolkit section 1.2, Dependent, independent and controlled variables

Method

List all the other factors that might affect the rate of dissolving. These are the controlled variables.

Then write a method for your investigation that makes sure that these controlled variables are not changed during the experiment. Use clear, numbered steps.

GO TO
Toolkit sections 2.1, Writing a method for an experiment, 1.3, Hypotheses and predictions and 3.3, Designing a results table

Materials

Write a materials list and safety notes for your investigation.

Prediction

Write a prediction for your investigation. Remember that a prediction must be specific to your experiment.

Results

Design a table to record your results.

Conclusion

1. Write a conclusion to your experiment by describing how well your results support your conclusion. Refer to your data in your conclusion as evidence.
2. Suggest why changing the temperature might affect how fast the sugar dissolves in the water.

Evaluation

Evaluate your practical investigation by suggesting two improvements to your method.

4.7 Evaporation and crystallisation

Learning intention

To understand how evaporation or crystallisation can be used to separate mixtures

Success criteria

SC 1: I can describe examples of evaporation and crystallisation in mixtures.

SC 2: I can describe changes to particle behaviour during evaporation and crystallisation.

SC 3: I can explain how evaporation followed by condensation can be used to separate a solvent from a mixture.

KEY TERM

non-aqueous solution a solution in which the solvent is not water

Lesson overview

Changes of state can often be used to separate mixtures. A simple example is salt in the oceans. If the seawater is warmed, the water will evaporate but the salt will not so the water can be removed from the seawater.

Another way to extract a dissolved substance from a solution is by not getting rid of all the solvent. Instead, extraction can be achieved by reducing the amount of solvent until there is not enough solvent to dissolve all the solute. At this point, some of the dissolved solute will form as solid crystals, which can be easily removed from the mixture.

In this lesson, you will learn about the processes of evaporation and crystallisation, including what is happening to the particles during these changes.

SC 1 I can describe examples of evaporation and crystallisation in mixtures

Examples of evaporation in mixtures

When two substances are combined in a mixture, the one with the lower boiling point will evaporate before the one with the higher boiling point. This is why evaporation can be used to separate the components of a mixture. In aqueous solutions, the water will evaporate to leave the solute behind. In **non-aqueous solutions**, the solvent, such as alcohol, will evaporate into the atmosphere.

Examples of 'everyday' evaporation include the production of sea salt from seawater, drying nail polish, cooking and tie-dying (Table 4.7.1).

TABLE 4.7.1 Examples of evaporation in everyday life

Sea salt is produced from the evaporation of water in seawater by heat from the Sun. 	The solvent used in nail polish is acetone, which evaporates to leave the coloured chemicals on the nail. Blowing air over the nail polish mixture helps to increase the evaporation rate. 	When cooking, evaporation is a common step, especially for the last stage of a dish. For example, to thicken a curry sauce, the food is boiled gently to evaporate water until the consistency is correct. 	Tie-dying relies on the solvent containing dissolved pigments. As the solvent evaporates, the pigments are left in the fabric of the clothing, producing vivid colours. 

Examples of crystallisation in mixtures

Crystallisation is the formation of a solid when a solution has become saturated, and the solute becomes a solid crystal (Figure 4.7.1). It can occur in aqueous and non-aqueous solutions.

This often happens because of the evaporation of the solvent.

The solubility of a solute may also depend on temperature, so getting exactly the right amount of solvent at the correct temperature can be tricky. If too much solvent is evaporated too quickly, there may not be enough time for the crystals to form into regular crystal shapes.

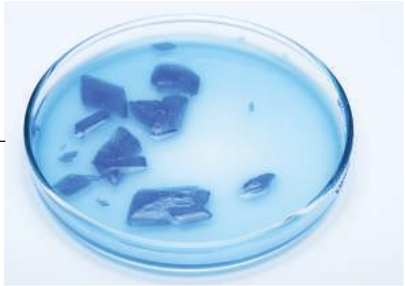
When the conditions of evaporation are carefully controlled, it is possible to form beautiful, regular-shaped crystals. Four examples of crystallisation are listed below.

FIGURE 4.7.1 Bright green crystals of the mineral dioptase.

Copper sulfate crystals

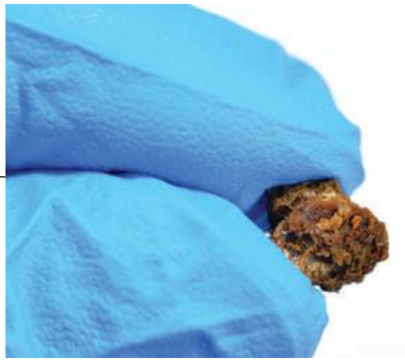
Copper sulfate crystals can easily be grown in the laboratory. A saturated solution of the cooper sulfate can be left to evaporate slowly.

Alternatively, a saturated solution is made using hot water and then the solution is cooled. Because the copper sulfate is less soluble at lower temperatures, less solute will dissolve, and solid copper sulfate will start to form.



Kidney stones

If urine contains too much solute, such as calcium compounds and uric acid, there may not be enough solvent to dissolve all the substances. These substances will then crystallise to form solid lumps called kidney stones, which can be extremely painful and potentially dangerous if not removed.



Crystallisation of sugar

Sugarcane is a type of giant grass that is crushed and the mixture filtered to remove impurities and then heated to evaporate some of the water. This produces a substance called molasses. As the molasses dries, crystals of raw sugar are produced.

Crystallisation of tree sap

Tree sap, such as the sap from an acacia tree, is a water-based solution. When exposed to the atmosphere, the water content will reduce, and the sap will crystallise into a solid.

The Gumbaynggir people, near what is now called Coffs Harbour, used this process in their medicine. They applied the sap of the Australian blackwood tree (*Acacia melanoxylon*) to a wound and as the solid crystals formed, they sealed the wound. Chemicals in the sap also acted as an antiseptic, reducing the risk of infection from bacteria.

SCIENCE IN SOCIETY

Crystallisation and mining in Australia

In Australia, crystallisation is an important process in the mining industry. Many people mine for gemstones in regions of Australia. Gemstones are crystals created by geological processes below the earth. Beautiful gemstones, such as diamond, sapphire and emerald, are discovered and sold for jewellery (Figure 4.7.2). Gemstones are also used for other purposes. For example, sapphire is used for lasers in scientific instruments and diamonds are used for cutting glass.

FIGURE 4.7.2 These emerald crystals were found in rocks mined in New South Wales

Crystallisation in mining is important for extracting valuable minerals and metals from ore (rock or sediment containing valuable minerals or metals). For example, in the production of alumina (Figure 4.7.3, a substance containing aluminium and oxygen), a solution containing dissolved alumina is allowed to cool, causing crystals to form. These crystals are then collected and processed to produce aluminium.

FIGURE 4.7.3 This alumina powder is ready to be processed into aluminium

Crystallisation is also used in the production of other minerals such as copper and nickel. By understanding the principles of crystallisation, mining companies can optimise their extraction processes, improving efficiency and reducing waste. This knowledge is essential for maintaining Australia's position as a leading producer of minerals and metals.

SC 1 CHECK YOUR UNDERSTANDING

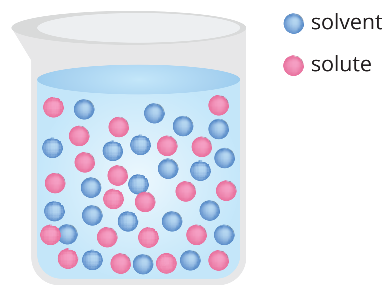
Explain how a lollypop is made by crystallisation.

SC 2 I can describe changes to particle behaviour during evaporation and crystallisation

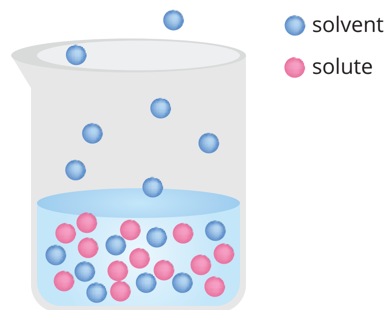
Fast evaporation from a solution and crystallisation

This section explores how fast evaporation will lead to the formation of a solid by observing the particle behaviour.

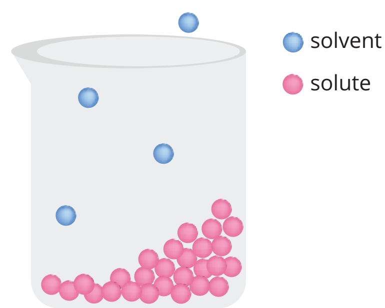
The solution
A solution will contain particles of a solute spread evenly among the particles of the solvent. The particles are too small to be detected visually so the solution appears clear.



Evaporation
If the number of solvent particles is reduced as the solvent evaporates, the distances between the solute particles will get smaller.



The solid forming
Eventually, if evaporation continues quickly, there will be no particles of solvent left. The particles of solute will now be in contact with each other and attractions between the particles will hold the particles in place.
As you know from particle theory, this is how the particles are arranged in a solid, so the solute will now be present as a solid.



If the evaporation has happened quickly, the particles are not able to form into regular arrangements. So, when solids are produced from fast evaporation there may be no visible crystals in the solid formed. Meanwhile, the solvent will be present as a gas (**vapour**) that will have diffused into the surrounding atmosphere.

KEY TERM

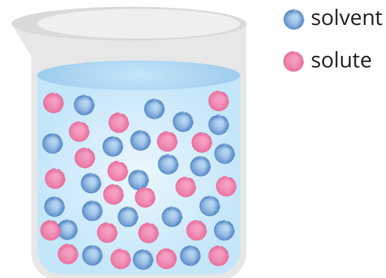
vapour matter that has been produced by evaporation from a liquid; can be a pure gas, as in water vapour in the atmosphere, or a mixture of a gas and small droplets of liquid

Crystallisation in a solution

When crystallisation occurs more slowly, the crystals form within the solution and the behaviour of particles is different (and a bit more complex) compared to fast evaporation.

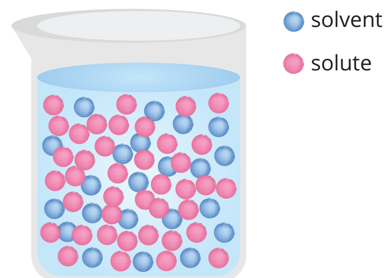
The solution

A solution will contain particles of a solute spread evenly among the particles of the solvent. The solute is soluble in the solvent.



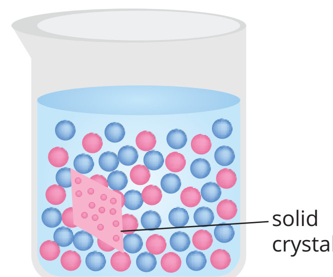
Making a saturated solution

If the concentration of the solute increases, the solution may become saturated, which means that the solvent contains the maximum number of solute particles that is possible. This can be achieved by either adding more solute, evaporating some of the solvent, or cooling the solution down to reduce the solubility of the solute in the solvent.



Crystallisation

As the attractions between the solute particles increases, some will join together in the solution. Other solute particles will be able to remain dissolved because there is now enough 'space' for them between the solvent particles. The process of crystallisation can be slow, which allows the particles to form regular arrangements. This is why crystals are often formed as regular shapes. Crystals of the same substance will often form into the same shape as the particles fit together in particular ways.

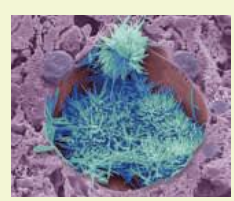


Note that, in this situation, the crystals have formed before all the solvent has evaporated. The crystals can be separated from the remaining solution by filtering (Table 4.7.2).

TABLE 4.7.2 Examples of the results of crystallisation

Pure copper sulfate crystals are normally a rhombus (diamond) shape.

Pure salt (sodium chloride) crystals are normally a cube shape.



A coloured image of hair-like crystals of cholesterol formed in a human liver caused by a high concentration of cholesterol.

SC 2 CHECK YOUR UNDERSTANDING

Explain what happens to copper sulfate particles during crystallisation.

SC 3 I can explain how evaporation followed by condensation can be used to separate a solvent from a mixture

When evaporation is used to separate the solute from a solution, the solvent is usually allowed to escape into the atmosphere. However, there are many situations where it is more important to collect the solvent. Examples of this include producing pure water from contaminated water, extracting essential oils from plant materials (e.g. lavender oil Figure 4.7.8) or extracting petrol or other fuels from crude oil (oil extracted from the ground contains many chemicals).

FIGURE 4.7.8 This apparatus can be used to extract lavender oil

Distillation

The process used to collect the solvent is called **distillation**. Distillation is the combination of evaporation followed by the **condensation** of the vapour.

The mixture is heated so that it boils. The vapour that is released is captured and then cooled. The cooling process causes condensation to occur, turning the vapour back into a liquid that can be collected in a different container.

Figure 4.7.9 shows the apparatus that can be used to carry out a distillation experiment to separate a mixture of water and a dissolved red solid. A heating mantle heats a round-bottom flask that contains the red solid dissolved in water. As the heating mantle increases the temperature inside the flask, the water evaporates, leaving a more concentrated red solution in the round-bottom flask. The water vapour passes through the condenser. A condenser is a glass tube that has cool water circulating through a hollow walled space. The circulating water does not mix with the vapour in the inner tube of the condenser; instead it cools the vapour, allowing it to condense back into liquid form. The liquid is then collected in a beaker.

The product of distillation, in this case, water, is called the **distillate**. The substance(s) left behind in the round-bottom flask is often called the residue.

KEY TERMS

distillation a process that uses evaporation followed by condensation to recover solvents from mixtures

condensation a change of state in which a gas is cooled and forms a liquid

distillate the product of distillation

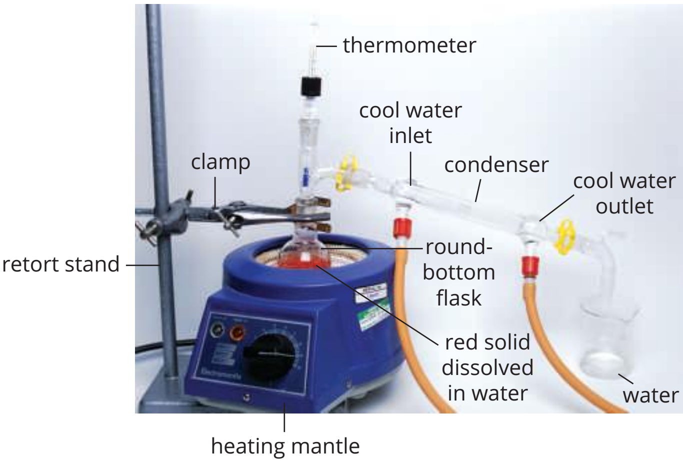


FIGURE 4.7.9 A basic set-up of a distillation experiment

Distillation in industry

Distillation can be used to produce huge amounts of products, including petrol from crude oil in an oil refinery (Figure 4.7.10) and essential oils from plant materials. Distillation can also be used to purify a range of products in the chemical industry.

Large-scale distillation can use a lot of energy because the mixtures often must be heated to high temperatures for them to boil. They also be carried out under strict safety regulations due to the potential dangers involved.

FIGURE 4.7.10 In this photograph of an industrial oil refinery you can see the pipes where the vapour is cooled and collected.

GO TO
Toolkit section 5.3, Drawing scientific equipment

SC 3 CHECK YOUR UNDERSTANDING

Describe what condensation is.

Lesson review

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

1 Explain how evaporation and condensation can be used together to separate a solvent from a mixture.

2 Compare the processes of evaporation and crystallisation when they are used to separate mixtures.

3 Describe the difference between fast and slow evaporation and crystal size.

4 Explain what happens to sugar particles during the crystallisation of sugar syrup.

5 Eucalyptus leaves contain many fragrant substances. To collect the fragrance from the lemon-scented gum (*Eucalyptus citriodora*), leaves are chopped up and boiled in water and the aqueous part of the mixture is collected by distillation.

   a Sketch the distillation set-up for this experiment.

   b Describe what happens to the water particles in the original mixture during the distillation process (from when they are heated by the heating mantle to when they are collected in the beaker).

4.8 Using evaporation and crystallisation

Introduction

Evaporation and crystallisation are both processes used to produce a solid substance from a solution. They therefore separate the solid from the solvent that the solution was made from.

In this practical investigation, you will produce salt by fast evaporation, slow evaporation and crystallisation, and you will investigate how the method of separation affects the size of the salt crystals produced (Figure 4.8.1).

Learning intention

To be able to investigate the role of heat in evaporation and crystallisation

Success criteria

SC 1: I can use knowledge of particle theory to develop a prediction.

SC 2: I can safely conduct an experiment, including recording qualitative data.

SC 3: I can construct a conclusion that links primary data with a scientific theory.

FIGURE 4.8.1 Salt is a substance that can be produced from a solution of saltwater by evaporation and crystallisation.

Background

A soluble substance will dissolve in a solvent to form a solution.

There are two processes involved in the separation of the solute from the solvent: evaporation and crystallisation. Evaporation is the removal of some or all of the solvent, often caused by heating the solution. Crystallisation is the formation of the solid form of the solute.

This experiment investigates how changing the method and rate of evaporation affects the products of the method of separation.

The rate of evaporation can be increased by heating the solution, which provides more energy for the particles.

Aim

To produce salt (sodium chloride) crystals by evaporation and crystallisation and compare crystal sizes produced through a fast process to those produced through a slower process of evaporation and crystallisation

Hypothesis

State whether you think rapid or slow evaporation and crystallisation will affect the size of crystals produced.

GO TO

Toolkit section 1.3, Hypotheses and predictions

Prediction

Read the experimental method and predict the appearance of the salt (sodium chloride) crystals produced by slow evaporation and crystallisation compared to those formed by fast evaporation and crystallisation.

GO TO
Toolkit section 2.2, Ethical behaviour and safety in science

Materials

- 2 × 50 mL concentrated salt (sodium chloride) solution or
  2 × 50 mL concentrated alum (potassium aluminium sulfate) solution
- evaporating basin
- Petri dish
- 100 mL beaker
- spatula or wooden 'pop stick'
- Bunsen burner, bench mat, tripod and gauze mat, or hotplate
- matches
- hand lens or stereo microscope and microscope slide

SAFETY NOTES

- Tie long hair back.
- Turn the Bunsen burner flame to yellow when it is not being used.
- Allow equipment to cool before packing it away.

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.

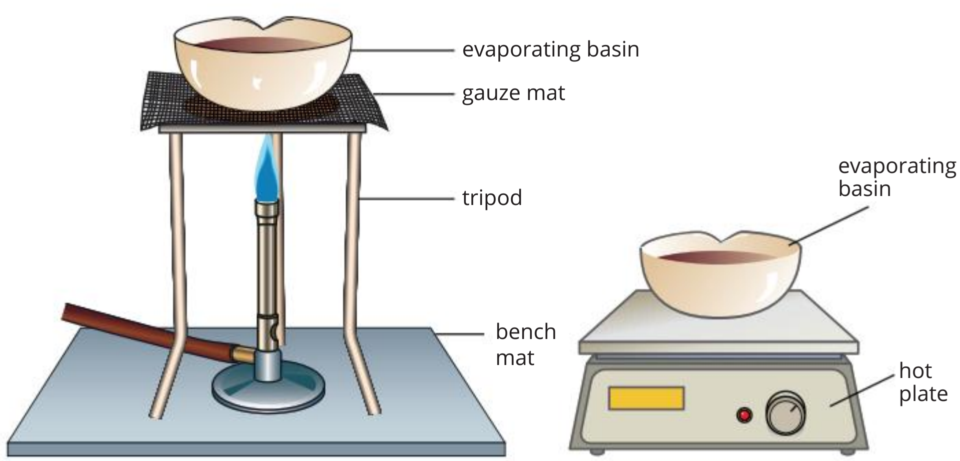
Method

Part A: Slow evaporation and crystallisation

1. Pour your solution into the Petri dish until it is about half full.
2. Set it aside somewhere in the room where it will not be disturbed and leave it for at least 24 hours.
3. The next day, observe the appearance of the crystals in the solution.
4. Examine the salt crystals formed with the hand lens or stereo microscope.

Part B: Fast evaporation and crystallisation

1. Set up the equipment as shown in the diagram. Do not turn on the Bunsen burner or hotplate yet.



2 Pour the solution into your evaporating basin until it is about half full.

3 Heat the solution with a small Bunsen burner flame, watching carefully that material does not 'spit' out of the basin (Figure 4.8.2). If it does spit, reduce the gas flow by adjusting the gas tap, or use the gas hose to move the Bunsen burner carefully in and out of the tripod. If you are using a hotplate, then start with high heat and then turn it down as the solution starts to evaporate.

4 When only a small pool of the liquid is left, turn the Bunsen burner or hotplate off. The rest of the liquid will evaporate with the heat left in the basin.

5 Allow the basin to cool for several minutes.

6 Examine the salt crystals formed with the hand lens.

FIGURE 4.8.2 A Bunsen burner can be used to evaporate a solvent from a solution more rapidly.

Results

Copy the results table below into your notebook and record your observations. You can use diagrams or text to describe your observations.

Rate of crystallisation	Appearance of crystals
Fast	
Slow	

Conclusion

Write your conclusion by answering the following questions.

1 Assess how accurate your prediction was and, therefore, whether your hypothesis was supported.

2 Propose a reason, in terms of particles, why one method produced larger crystals than the other.

GO TO
Toolkit section 4.1, Evaluating investigations

4.9 Chromatography

Learning intention

To be able to use chromatography to separate and compare coloured mixtures

Success criteria

SC 1: I can predict solutions that would be able to be separated by chromatography.

SC 2: I can conduct a chromatography experiment using a method that is reproducible.

SC 3: I can develop a conclusion from observed qualitative data.

FIGURE 4.9.1 The mixture is separated by a solvent travelling through a stationary material, in this case, paper.

KEY TERMS

chromatography a method of separating a mixture by making it move over or through another stationary material

chromatogram the result from a chromatography experiment

Introduction

Chromatography is used to separate two or more substances (solutes) that are both dissolved in one solvent (for example, in Figure 4.9.1). It is often used to separate coloured substances. The word comes from the Greek *chroma*, meaning 'colour' and *graphein*, meaning 'to write'.

In this practical investigation, you will learn how the process of chromatography works and apply the method to compare different mixtures of colours.

Background

There are many different types of **chromatography** but they all work in a similar way.

- The mixture to be separated is placed on a material. (This material is called the stationary phase).
- A solvent, in this case, water, moves through the material. (This solvent is called the mobile phase).
- In paper chromatography, the water moves up through the paper by a process called capillary action.
- As the water (mobile phase) moves through the mixture being separated, soluble components will be dissolved and are carried along by the solvent.
- Each component may have a different force of attraction with the material that it is attached to and they might also have different levels of solubility with the solvent.
- Because of these differences, the components will be moved different distances along the stationary phase (the paper).
- Hence the mixture can be separated (Figure 4.9.2).

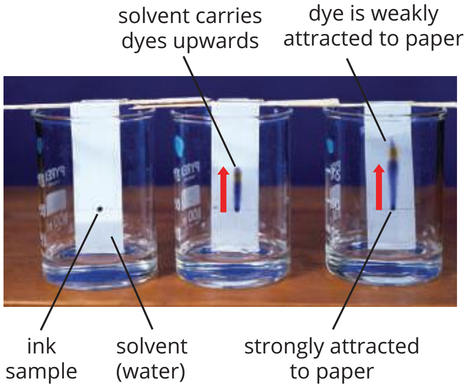


FIGURE 4.9.2 The yellow dye is separated from the blue dye in the ink mixture as the water moves up the paper, dissolving the liquids.

The result of chromatography is called a **chromatogram**.

Aim

To learn how to produce a chromatogram and to use chromatography to compare different mixtures

Materials

- 1 strip of chromatography paper or filter paper
- pencil and ruler
- water-soluble felt-tipped pen
- 100 mL beaker
- straw (or toothpick)
- paperclips

For Part B only:

- one rectangle of chromatography paper or filter paper 10 cm × 8 cm
- 6 different coloured water-soluble markers

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 the beaker is not knocked over while setting up the experiment.

Method

Part A: Producing a chromatogram

1 Use a pencil and ruler to draw a horizontal straight line 2 cm from the bottom of the chromatography paper strip.

2 Use the felt-tipped pen to add a spot of ink about 2 mm across on the centre point of the pencil line.

3 Place 1 cm of water in a beaker.

4 Use the straw or toothpick and the paperclip to suspend the chromatography paper in the solution so that the spot of ink is above the surface of the liquid and the paper is not touching the bottom of the beaker.

5 Leave for about 10 minutes, and then remove and dry the chromatogram by carefully laying it down on a paper towel.

HINTS

Make sure that the spot of ink is above the surface of the water when the paper is hanging in the beaker. You may want to practise getting the height right before you add water to the beaker.

Do not be tempted to use a larger dot of ink.

Part B: Using chromatography to compare mixtures

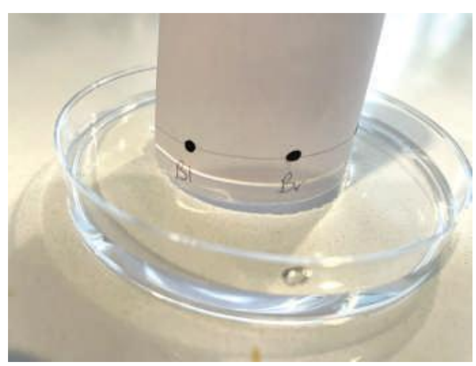
1 Using a pencil, draw a line across the chromatography paper, 2 cm from the bottom, and mark 6 spots evenly spaced on this line.

2 Take the pens and mark one ink spot on top of each line to give you six different coloured spots along the line.

3 Using the pencil, label the spots with the names (or abbreviations) of the colours.

4 Use the paperclip to hold the chromatography paper in a cylinder. Make sure there is a gap of about 1 cm at the bottom so that the paper does not overlap itself.

5 Add water to the Petri dish and carefully place the chromatography paper cylinder into the water and leave. Do not attempt to move the Petri dish or chromatography paper once the paper is placed in the water.



6 When the water has almost risen to the top of the paper, take the chromatogram out of the water, remove the paperclip and place the paper flat on a paper towel to dry.

Results

Record the results by either taking photos of the chromatograms or sticking the chromatograms into your notebook.

Part A	Part B

Conclusion

Write your conclusion by answering the following questions.

Part A

1 Describe what your observations revealed about the ink in the water-soluble marker.

2 Explain how the water helped to separate the coloured dyes.

3 Predict what would have happened if you had tried using a permanent marker for this experiment. Explain your answer.

Part B

4 List all the pens that contained ink that was a mixture of different colours.

5 The colours in the ink that were most soluble went furthest up the paper. Name the colour that was the most soluble in water and the colour that was the least soluble in water.

6 Copy and complete the table below in your notebook to show all the colours present in each of the coloured pens.

Colour of the pen						
Colours in the ink						

Evaluation

Explain the advantage of having all the pens on the same chromatography paper.

4.10 Separation techniques used by First Nations Australians

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, filtering, sieving and steam distilling.

SC 2: I can describe how First Nations Australians use specific products from separation techniques.

Lesson overview

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 have contributed to modern understandings of ecology and sustainability. First Nations Australians use many separation techniques (Figure 4.10.1), which maximise the use of natural materials to produce substances that are useful in many areas including nutrition, health and hygiene.

FIGURE 4.10.1 Seeds can be separated from waste material by techniques such as yandying and winnowing.

In this lesson you will learn how groups of First Nations Australians use separation techniques, including hand-picking, sieving, winnowing, yandying, filtering and steam distilling.

SC 1 I can describe ways that groups of First Nations Australians separate mixtures, including hand-picking, winnowing, yandying, filtering, sieving and steam distilling

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. Some of these separation techniques are explored on the following pages.

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 4.10.2).

The Anangu 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.

FIGURE 4.10.2 Materials that are visually different, like this range of seeds and berries gathered in in the Northern Territory, can be separated by hand-picking.

Winnowing

Winnowing separates lighter objects, like husks or seed shells, from heavier or denser materials such as the seeds themselves (Figure 4.10.3). 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. The lighter materials will get blown away but the heavier items will fall back into the container to be collected. The term koolamon (also spelled 'coolamon') is an anglicised word from the language of the Kamilaroi people of northern New South Wales and southern Queensland. 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 km in the region now recognised as the Northern Territory.

FIGURE 4.10.3 Winnowing to separate rice from its husk is the same process used by First Nations Australians to separate seeds and pods.

Yandying

Yandying is like winnowing because it is used to extract heavier, useful materials from lighter waste materials (Figure 4.10.4). 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.

Yandying has widespread use across Australia, but the term, yandy, is thought to originate from the Yindjibarni people from the north-west of what is now called Western Australia.

FIGURE 4.10.4 Traditional wooden yandies

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, whereby 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

FIGURE 4.10.5 A traditional jawun basket is used as a sieve in North Queensland.

First Nations communities living in the rainforest areas of north-eastern Queensland, for example, know that some edible seeds also contain toxic chemicals. The Ngadjon people weave jawun (bicornual or 'two horned') baskets to help detoxify cycad nuts (Figure 4.10.5). The nuts are placed in the basket, which is then fixed in place in a flowing river or stream. After a few days, the toxins have dissolved in the water and been carried away while the seeds remain trapped in the basket. Afterwards, the nuts can be made into cakes that are safe to cook and eat. The unique structure of these baskets, and the resilient lawyer cane that they are made out of, allow them to sit for a long time in moving water without the material losing its strength.

Steam distillation

Steam distillation is used to extract aromatic oils from native plants. Fresh, damp leaves are placed on top of smouldering fires until the water turns into steam, which passes through the plant material. The high temperature of the steam thus causes the oils to evaporate, allowing for the extraction of oil because of their low boiling point.

Because there is no easy way for the vapourised oils to be collected outside of a laboratory, people requiring treatment used to place themselves close to the fire so they could breathe in the vapours directly. For example, the Bundjalung people of northern NSW would heat tea tree leaves and breathe in the vapours to treat coughs and colds. Nowadays, however, the vapours drawn from steam distillation can be condensed and collected.

Tea tree (*Melaleuca alternifolia*) oil is one of the essential oils that First Nations Australians extract by steam distillation. It is widely used both as an antiseptic and as herbal medicine (Figure 4.10.6).

FIGURE 4.10.6 Tea tree oil and the leaves of *Melaleuca alternifolia* from which it is extracted

SC 1 CHECK YOUR UNDERSTANDING

Explain how sieving is used to separate mixtures.

SC 2 I can describe how First Nations Australians use specific products from separation techniques

Separation techniques used by First Nations Australians generally rely on the different properties of substances in a mixture. In filtering, for example, a substance that is soluble in water, such as the toxins in a berry, can be separated from the insoluble fruit by suspending a basket in a river. These processes do not always produce pure substances; the products may still have more than one component, but there will be fewer components mixed. Accordingly, the berries still exist as a mixture of substances, but separation of the toxin has made them useful: in this case, safe to eat.

Indeed, useful substances often display their properties only once they have been separated. Extracting medicinal oils such as eucalyptus and tea tree oil from the plant, for example, makes them more effective, either by allowing them to be more easily absorbed by the body or by increasing the concentration of the active ingredient.

First Nations Australians use a range of separation techniques to produce useful products.

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 4.10.7). The Gunditjmara people of south-western Victoria use this technique to drink safely from various sources of fresh water.

FIGURE 4.10.7 This is a banksia cone in flower. You can see how the structure of the flowers resembles a filter.

Essential oils

Some of the most common ways in which First Nations Australians use essential oils are 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 4.10.8).

FIGURE 4.10.8 A smoking ceremony at the Darwin Festival in 2022

FIGURE 4.10.9 Wattle seeds require separation from their seed pods and other waste material before consumption.

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 4.10.9). The seeds 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 4.10.10 The Kakadu plum is found in northern parts of Western Australia, the Northern Territory and Queensland.

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 4.10.10). It also goes by a number of other regional names, including the gubinge, the kabiny and 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 4.10.11 Leaves of the red ash, or soap tree

Soap

The red ash tree (*Alphitonia excelsa*) contains a chemical called saponin in its leaves that can be used as soap (Figure 4.10.11). 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.

SC 2 CHECK YOUR UNDERSTANDING

Describe the separation techniques used by First Nations Australians to obtain seeds for food.

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 by 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.

4.11 Testing separation techniques

Introduction

Evaporation, filtering, sieving (Figure 4.11.1), crystallisation, distillation and chromatography are all methods of separation that scientists can use to produce pure substances from mixtures. Choosing the correct technique depends on knowing about the properties of the substances in the mixture. Once the technique has been identified, the scientist can design the 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.

FIGURE 4.11.1 Sieving is a simple method of separating out larger particles from smaller particles.

In this inquiry activity, you will be presented with a mixture to separate and have the challenge of designing 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 test the best way to separate a mixture

Success criteria

SC 1: I can suggest 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

All the techniques you have learnt about so far depend on the properties of the substances in the mixture. More specifically, you need to identify a difference in the properties.

For example, if one substance dissolves in water and the other one does not, filtering can be used. If one substance does not dissolve well in cold water and the other one does, crystallisation can be used.

Aim

To design, trial and evaluate a separation technique

HINT

When you plan your investigation, make sure that you know which substance you are trying to collect (the product), and which substance you can discard (the waste).

Plan

Plan how you will carry out your separation investigation.

- Write your method in a series of numbered steps.
- Include any materials and 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.

GO TO

Toolkit sections 2.1, Writing a method for an experiment, 2.2, Ethical behaviour and safety in science and 5.3, Drawing scientific equipment

Conduct

1 Copy the table into your notebook and write three success criteria that you can use to determine the effectiveness of your method.

Success criteria for separation method	Comment

2 Conduct your investigation.

3 As you work through your method, note your observations and ideas for improvements to your inquiry activity.

HINTS

To determine how successful your activity was, you can ask yourself:

How much product did I/we produce?

Did I/we remove all the waste product?

Improve

Describe how you can improve your separation method. Use the notes that you made during the experiment to help you.

Evaluate

Use your three success criteria to evaluate the effectiveness of your separation method.

4.12 Recycling education campaign

Introduction

Science communication plays an important role in informing individual viewpoints and community policies and regulations. With a current focus on caring for the environment, individuals and communities are working hard to reduce waste and recycle as much as they can. This can be promoted through education and communication about how to recycle and the benefits this provides to the environment.

In this inquiry activity, you will be able to describe the impact science communication has on sustainable separation techniques such as recycling.

Learning intention

To be able to describe the impact science communication has on sustainable separation techniques such as recycling

Success criteria

SC 1: I can describe how separation techniques are used in recycling.

SC 2: I can describe how communicating about recycling encourages community action and initiatives.

SC 3: I can develop communication material, such as a poster or video, for an education campaign about recycling.

Background

There are several separation techniques used in recycling (Figure 4.12.1). These are designed to separate paper and cardboard, plastic, metal, electronics, wood, glass, clothing and textile, bricks and inert (non-biodegradable) waste.

Various strategies are used to separate this waste. The processes may differ from the home, school and commercial environments. Science communication can have a big influence on sustainable separation techniques such as recycling. Many highly successful communication strategies around the world aim to increase awareness about recycling.

FIGURE 4.12.1 Manual sorting is sometimes required for mixed recycling facilities.

Aim

To investigate various separation techniques and create an education campaign about a recycling strategy

Plan

1. Start to plan your investigation by exploring various separation techniques that are used for recycling. Write a short summary about three separation techniques.
2. List materials that can be recycled and how they are recycled at school, home and in the community.

HINT

Explore your local council's website to see how your local community separates their waste.

Design

1. Choose a particular recycling strategy you would like to focus on for your education campaign. Write the name of the recycling strategy and explain why you chose it.
2. Describe how you will communicate important information about this recycling strategy to your target audience. Consider the following:
   - What format will you present this information in (e.g. video, animation, poster, pamphlets)?

GO TO Toolkit sections 4.2, Referencing secondary data and 4.3, Selecting and using secondary data

FIGURE 4.12.2 Consider how this toilet paper company entices people to use its toilet paper; their slogan is 'good for the world, good for people, good for your bum'.

FIGURE 4.12.3 How does this company reuse these containers and reduce waste to landfill?

GO TO

Toolkit sections 5.1, Scientific writing, 5.2, Scientific diagrams and 5.4, Graphic organisers

- What elements will you use to communicate your message (e.g. animation, photos, text, voiceover)?
- Where will this information be communicated?

3 Explore the education campaigns in Figures 4.12.2 and 4.12.3 and consider how they have been effective in communicating their message. Outline how you could incorporate some of their successful messaging in your campaign.

Conduct

You will now have an opportunity to create your education campaign using the learning from your planning and design. Consider the questions below to guide the creation of your campaign.

- What is recycling and why is it important?
- What recycling strategy are you focusing on and what materials are involved?
- What separation techniques are used?
- How does this strategy benefit society and the environment?
- Where can people find further information about this recycling strategy?

Improve

Share your education campaign with your class and your teacher and record any feedback that you receive.

Describe how you can improve your campaign by considering the following questions.

1 What aspects of your planning and design work well in an education campaign?

2 What aspects of your planning and design need improvement?

3 How could you modify your education campaign to make it more effective?

Evaluate

Evaluate your investigation by considering the following questions.

1 What aspect of recycling and separation techniques were you investigating in this inquiry activity?

2 In this activity, you created an education campaign for a particular recycling strategy. What skills did you use during this activity?

4.13 Influence of cultural perspectives on scientific research

Lesson overview

Culture and context continue to have an important influence on scientific research and discovery. Scientists interpret their hypotheses and develop their theories in a way that is influenced by the culture within which they live.

In this lesson you will learn about Veena Sahajwalla, a leading expert in the field of recycling science, and how culture influenced her scientific discoveries in the field of chemical sciences and recycling.

Learning intention

To understand how culture and context influence scientific research and discovery

Success criteria

SC 1: I can explain how cultural perspectives influence scientific knowledge.

SC 2: I can describe why Veena Sahajwalla's childhood experiences in Mumbai influenced her scientific research and discovery today.

SC 3: I can describe Veena Sahajwalla's innovations in the field of recycling science.

SC 1 I can explain how cultural perspectives influence scientific knowledge

Culture has an important influence on the types of scientific research that occur. Culture has been called 'the way of life for an entire society'. It encompasses the ideas, customs and social behaviours of a population that are passed down from generation to generation.

Aspects of culture include:

- societal values and codes of manners
- power structures
- religion and religious beliefs
- language and methods of communication
- education
- distribution of wealth
- peoples understanding of issues.

All these will affect how people, including scientists, think about the world around them.

Many scientists interpret their hypotheses and develop their theories in a way that is influenced by the culture in which they grew up in or live. Below are five historical and contemporary examples of where culture has had an impact on scientific knowledge and discovery.

KEY TERM

culture a combination of the values, beliefs, language systems, communication and practices that people share

Ancient Greek culture

The ancient Greeks represented the movement of planets in a way that adhered to their religious and cultural conventions. They believed in a heliocentric system, which means they believed the Sun was at the centre of the solar system. This was reflected in their models of the solar system. One model, as seen in Figure 4.13.1, is an orrery, a mechanical device that illustrates the relative positions and motions of the planets and moons in the solar system.

FIGURE 4.13.1 This is an orrery from ancient Greece, which models the Sun at the centre of the solar system

Indigenous knowledge

Indigenous knowledge has contributed to various scientific fields, including medicine and environmental management. This traditional wisdom offers valuable insights and complements modern scientific research. For example, cultural burning is a traditional fire management practice used by First Nations Australians. This technique helps manage vegetation and reduce bushfire risks, demonstrating the importance of cultural context in scientific practices.

Health and vaccines

FIGURE 4.13.2 Testing vaccines to fight influenza

Another example is the invention of vaccines. This innovation was born out of the need to prevent disease. Dr Edward Jenner, in 1796, created the very first vaccine. Dr Jenner observed that women who collected milk from cows and became infected with the less serious disease of cowpox were not contracting the deadlier smallpox. He successfully tested his theory that cowpox protected the milkmaids from smallpox.

The very first flu vaccine was invented in 1938 and was widely used to vaccinate United States soldiers during World War II (Figure 4.13.2). The deadly influenza pandemic of 1918–1919 prompted researchers to find an effective vaccine to prevent a future outbreak. Once scientists discovered that influenza was a virus in the 1930s, they were able to create the first flu vaccination from inactivated influenza.

Disease awareness

A recent contemporary example of the cultural influence on scientific discoveries is the cultural change around smoking. Contemporary science has provided greater knowledge about the risks of smoking, and this has resulted in fewer people smoking cigarettes. As well, laws have been created to protect the general public from second-hand smoke. For example, since 2001, smoking has been banned in Victorian cinemas, shopping centres, restaurants and other places where the general public are indoors.

Environmental awareness

FIGURE 4.13.3 Microplastics found in sand that has been washed up by the sea

Culturally, there has also been a significant focus on environmental sustainability. This global focus has become increasingly more important due to the increase in natural disasters, reduction of easily available resources and the changing climate around the world. With this, society is moving away from using plastics due to increased research and knowledge into the effects of microplastics (Figure 4.13.3) in food.

With the increasing awareness of environmental sustainability, there have been many scientific discoveries that have come out of the need to care for the environment. Some of these discoveries are biodegradable plastics, electric vehicles and meat alternatives.

SC 1 CHECK YOUR UNDERSTANDING

Describe three examples of cultural perspectives that can influence scientific research.

SC 2 I can describe why Veena Sahajwalla's childhood experiences in Mumbai influenced her scientific research and discovery today

Veena Sahajwalla

Veena Sahajwalla (Figure 4.13.4) is a leading expert in the field of recycling science and is the Founding Director of the Centre for Sustainable Materials Research and Technology at the University of New South Wales (UNSW). Veena is known internationally as the inventor of 'green steel', a cleaner alternative to using coal in the steel production industry. She invented an industrial process that used waste plastic bottles instead of coal, turning waste plastic into a resource. Further research extended the use of old car tyres as a source of carbon to replace the coal.

FIGURE 4.13.4 Professor Veena Sahajwalla

Childhood influence in India

Veena was born in Mumbai, India, and her childhood in Mumbai had a significant influence on her passion for recycling science today. Mumbai is the industrial heartland of India and everything in Mumbai has value and potential. Veena was intrigued by people who earned income collecting waste, like paper or glass, or repairing items (Figure 4.13.5). This inspired her to focus on recycling.

FIGURE 4.13.5 Two women in India sorting through waste to recycle

'Growing up in Mumbai, in India, where I was born, there was no such thing as waste. Everything had value and everything had potential.'

Quote from Veena 'The Tipping Point: Veena Sahajwalla' *Australian Story*, Australian Broadcasting Network.

Facts about Veena Sahajwalla

Figure 4.13.6 summarises the facts about Veena Sahajwalla.

A daughter
Veena's mother was a doctor and her father was an engineer. They were influential in her passion for the sciences.

A Mumbai child
Veena grew up in Mumbai, the industrial heartland of India. She believes that nothing in Mumbai was seen as waste and that everything had value and potential.

A pioneer
Veena was the only woman in her science and engineering class in India. She graduated top of her class.

A visionary
Veena sees all types of waste as an opportunity and an untapped resource waiting to be used.

An inventor
Veena's most famous innovation is green steel. This technology uses end-of-life rubber tyres and waste plastic as an alternative to coking coal as a fuel to power the production of steel.

A 'waste queen'
Veena is known as the 'waste queen'. She is transforming what people know about waste, not just in Australia but across the world.

FIGURE 4.13.6 Facts about Veena Sahajwalla

SC 2 CHECK YOUR UNDERSTANDING

Explain how Veena Sahajwalla's experiences in Mumbai influenced her focus on recycling and sustainability.

FIGURE 4.13.7 Used car tyres can be used in the green steel process

FIGURE 4.13.8 Professor Veena Sahajwalla has researched how bio-resources can be used in the steel-making process.

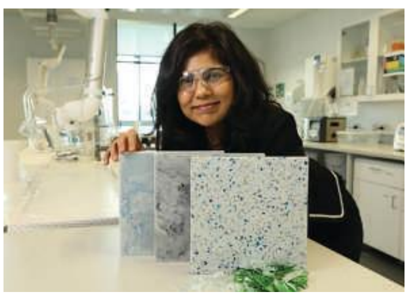


FIGURE 4.13.9 Ceramic tiles made from textiles and glass

SC 3 I can describe Veena Sahajwalla's innovations in the field of recycling science

Veena Sahajwalla grew up in Mumbai, where waste was seen as an opportunity rather than a problem, inspiring her to lead innovations in recycling science.

In 2003, Veena invented polymer injection technology, which produces 'green steel' using end-of-life rubber tyres (Figure 4.13.7) and waste plastic as alternatives to coking coal. Coking coal, converted to coke, is traditionally used in blast furnaces for producing iron and steel and represents the largest use of coal in the steel industry.

Thanks to Veena's innovation, millions of passenger vehicle tyres have been diverted from landfills in Australia, and the technology is now commercialised globally. Ongoing research explores using bio-resources such as coffee grounds, plastics and rubbers in the steel-making process (Figure 4.13.8).

In 2008, Veena founded the UNSW Centre for Sustainable Materials Research and Technology, home to micro-recycling science and technologies. The centre unites researchers from science, engineering and design disciplines to collaborate with industry in developing innovative, sustainable materials and manufacturing processes.

In 2018, Veena launched the world's first e-waste micro-factory, addressing the global issue of electronic waste. This facility transforms hard plastic components from discarded electronics, such as laptops and smartphones, into valuable materials like 3D printer filaments, reducing landfill waste.

Veena continues to innovate, recently creating 'green' ceramics from waste textiles and glass. For example, an old school uniform and a drinking glass could be transformed into ceramic tiles, potentially installed in bathrooms one day (Figure 4.13.9).

SC 3 CHECK YOUR UNDERSTANDING

Explain how Veena Sahajwalla's 'green steel' innovation benefits the environment.

Lesson review

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

1. Describe how traditional ecological knowledge of First Nations Australians can influence environmental science.
2. List two innovations by Veena Sahajwalla in recycling science.
3. Explain the role of e-waste micro-factories in managing electronic waste.
4. Predict the potential long-term impact of Veena Sahajwalla's innovations on global recycling practices.
5. Compare the significance of Veena Sahajwalla's green steel and e-waste micro-factory innovations and evaluate their contributions to sustainability.

4 Mixtures and methods of separation

Topic summary

The key concepts included in this topic are:

- The random movement of gas or liquid particles in another gas or liquid results in diffusion.
- Pure substances contain particles from only one substance whereas mixtures are two or more substances.
- Soluble substances form solutions.
- Insoluble substances form suspensions.
- Temperature controls the rate of dissolving solutes into solvents.
- Methods of separating out substances in mixtures can include filtration, sieving, evaporation, crystallisation, distillation and chromatography.
- First Nations Australians used various separating techniques to produce useful products.
- Culture and context influence scientific research and discovery.

Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

Remember

1 Describe diffusion by using the example of the brown-coloured gas, bromine, escaping into the surrounding air once the stopper is removed.

2 Explain the role of heat in evaporation.

Understand

3 Which of the following are pure substances? Note, there may be more than one correct answer.

A tap water
B cotton fabric
C gold bullion
D steam

4 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

5 A student has table salt and water and wants to design experiments to test the effect of temperature on:

a how fast salt dissolves in water
b crystallisation of salt in salty water.

For each test, briefly explain how you would design these investigations.

6 Describe how you would use paper chromatography to separate the colours in a water-soluble pen.

7 Describe how First Nations Australians might use yandying to separate seeds from sand.

8 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

9 A student pours concentrated cordial into a glass of water. The diluted solution appears clear.

- a Explain how the cordial diffuses through the water.
- b Classify the final mixture as a solution or a suspension.
- c Classify the concentrated cordial as soluble or insoluble.
- d Compare the speed of diffusion of cordial in room temperature water and in water containing ice.
- e The cordial mixture sat on a shelf for a week. The student observed crystals had formed on the glass. Identify the type of separation that has occurred and explain your reasoning.

10 Compare the effectiveness of using distillation versus evaporation to separate a solid from a liquid.

11 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 ways that you can use to separate the items.

12 Describe how Veena Sahajwalla's innovations could be applied in industries where raw materials are currently used in manufacturing.

13 Explain how filters can separate substances in the air and provide two examples of gas filters.

Extension: Research task

14 Food organics garden organics (FOGO) is organic waste from both the kitchen and garden; for example, 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. FOGO is converted to organic compost on an industrial scale. However, people (intentionally or unintentionally) add contaminants in the FOGO bin.

Three common contamination items are rocks, stickers on fruit, and metal.

Research how would you separate these items from 1 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 particular areas that you are confident in, and others where you are not so sure.

4 Glossary

aqueous solution a solution in which water is the solvent

chromatogram the result from a chromatography experiment

chromatography a method of separating a mixture by making it move over or through another stationary material

concentrated 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

condensation a change of state in which a gas is cooled and forms a liquid

crystallisation evaporation of a solvent from a solution, leaving solute behind as crystals

culture a combination of the values, beliefs, language systems, communication and practices that people share

diffuse spread out

diffusion a process in which two liquids or two gases mix due to the motion of their particles

dilute a solution that has a small amount of dissolved solute compared to the amount of solution

dissolve to mix completely with liquid

distillate the product of distillation

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 the liquid that passes through the filter paper

gaseous in the form of a gas

insoluble unable to dissolve in a particular solvent

mixture a combination of two or more pure substances that can be separated to recover the pure substances

non-aqueous solution solution in which the solvent is not water

particle a tiny part of matter; includes atoms and molecules

particle model a representation used to help describe and explain the behaviour of particles in solids, liquids and gases

particle theory the theory that states that all matter consists of tiny particles that are constantly moving

pure substance a substance that is made up of only one type of material

residue the solid left in the filter paper after filtration

saturated solution a solution that contains as much dissolved solute as possible

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 a material that has physical properties; a solid, liquid or gas

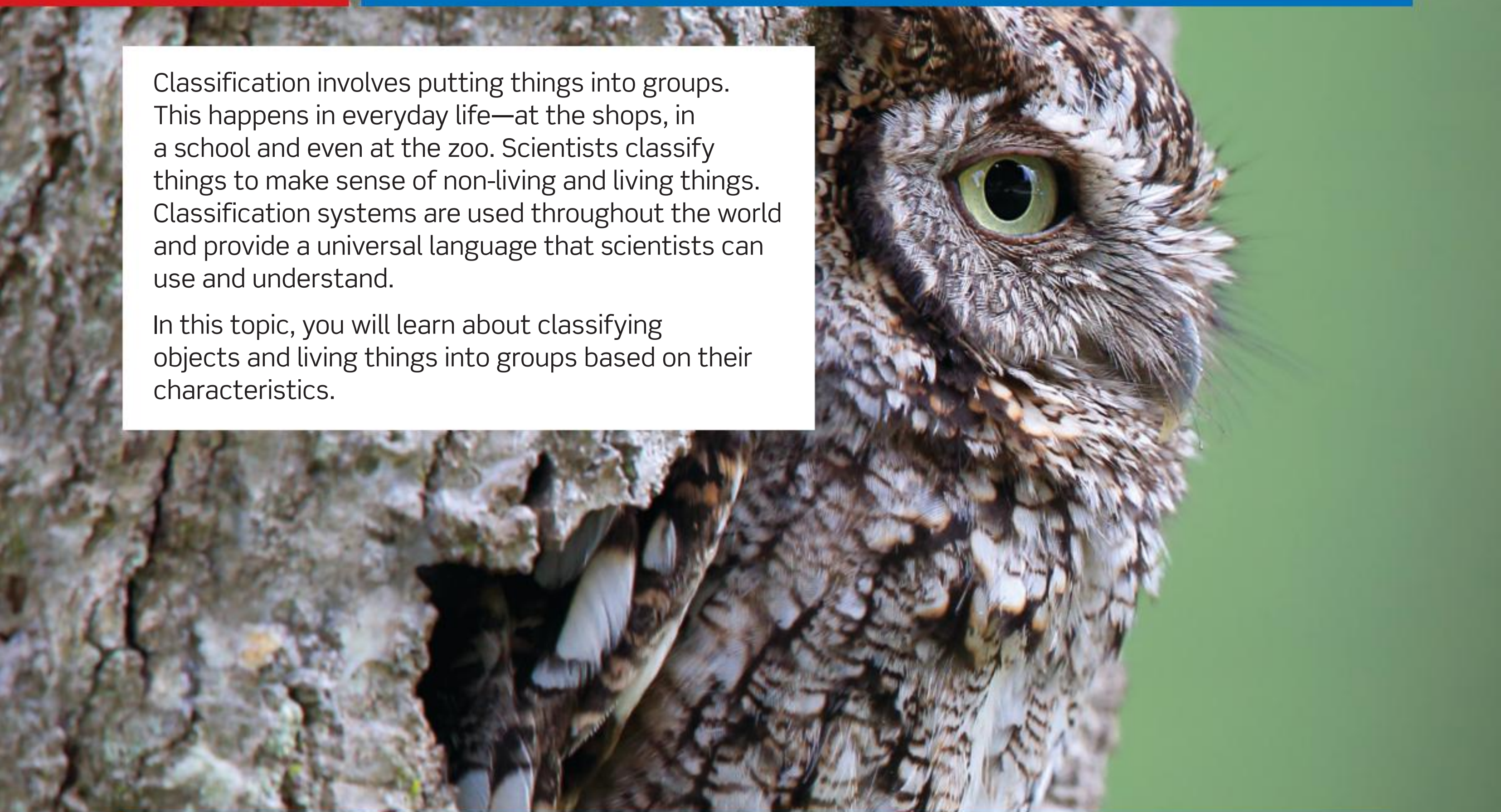
suspension a mixture in which a substance will not dissolve in another and separates out if left to stand

toxin a poisonous substance

vapour matter that has been produced by evaporation from a liquid; can be a pure gas, as in water vapour in the atmosphere, or a mixture of a gas and small droplets of liquid

TOPIC 5

Classification and biodiversity



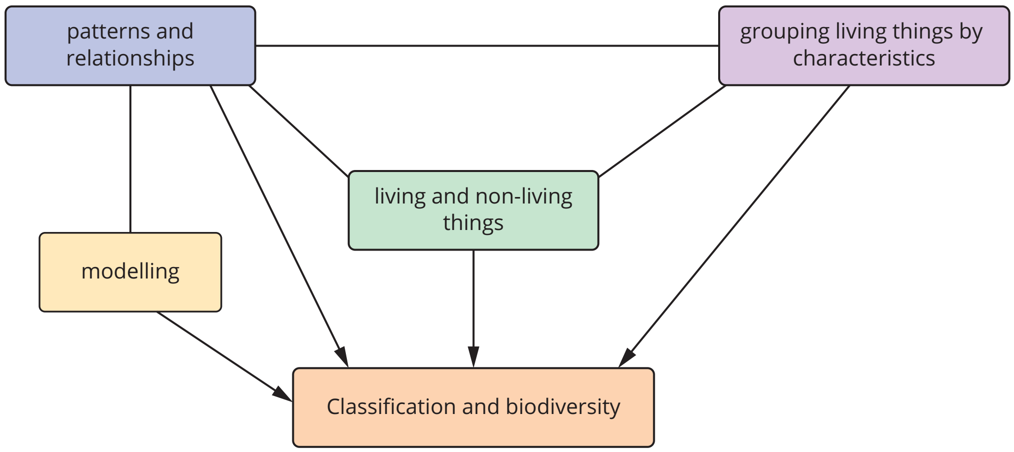
Classification involves putting things into groups. This happens in everyday life—at the shops, in a school and even at the zoo. Scientists classify things to make sense of non-living and living things. Classification systems are used throughout the world and provide a universal language that scientists can use and understand.

In this topic, you will learn about classifying objects and living things into groups based on their characteristics.

Learning intentions

5 Classification and biodiversity

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 '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 and 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 Introduction to classification

Lesson overview

Classification is an important concept in science. It is easier to understand 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. This simplifies the task of finding the product you are looking for. Classification in science is like 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 and their critical role in identifying the many living things on Earth.

Learning intention

To understand why organisms are classified

Success criteria

SC 1: I can describe the role of classification of biodiversity on Earth.

SC 2: I can describe at least two reasons for classifying the diversity of life on Earth.

SC 3: I can suggest how classification systems are affected by cultural perspectives and world views.

SC 1 I can describe the role of classification of biodiversity on Earth

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**.

The first person to suggest a classification system for life on Earth was Carl Linneaus, who lived in the 1700s. His approach described the relationships between living things and their environment with a focus on plants. Still used today, the Linnaean system organises living things into different levels or **hierarchies**, although many adjustments have been made to it over time.

Look at some of the other classification systems used across the sciences and think about the ways that different patterns and features are used to group a wide range of things.

KEY TERMS

classification the process of putting things into groups
diversity the variety of differences
characteristic a feature of a living or non-living thing
hierarchy an arrangement that shows items at different levels
state one of the three forms that matter can exist in—solid, liquid or gas

Chemists

Chemists classify substances based on their structure, colour and the **state** that they occur in at room temperature. For example, oxygen and carbon dioxide are gases, mercury is a liquid, and metals such as magnesium and iron are solids (Figure 5.1.1).

FIGURE 5.1.1 **(a)** Magnesium is classified as a metal because of its properties including colour, shininess, strength and ability to conduct electricity. **(b)** Although mercury is a metal, at room temperature it is liquid rather than solid.

Astronomers

There are differences between stars, planets and comets that enable astronomers to classify new 'heavenly bodies' when they encounter them (Figure 5.1.2). For instance, stars are massive glowing spheres of hot gas that produce their own light, while planets are smaller objects that orbit stars, like Earth in the solar system.

Geologists

Geologists classify rocks according to characteristics such as colour, hardness and the way they are structured (Figure 5.1.3). Igneous rocks are formed from molten magma cooling and solidifying deep within Earth, and these rocks often have a coarse texture. Sedimentary rocks are created when layers of sediment, like sand or mud, compact and harden over time, often producing a layered appearance.

FIGURE 5.1.2 Astronomers track celestial bodies, such as Halley's comet, which will pass by Earth in 2061.

FIGURE 5.1.3 Geologists sorting rock and mineral samples according to colour

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. As in the examples of other fields of science above, patterns and features are also used to classify **organisms** within this huge variation. By classifying organisms into groups at multiple levels, scientists can better understand the survival and behaviour of living things.

SC 1 CHECK YOUR UNDERSTANDING

Define the term 'classification' in the context of biodiversity.

SC 2 I can describe at least two reasons for classifying the diversity of life on Earth

FIGURE 5.1.4 Classification systems can be applied to all living things on the planet.

There are millions of different living things on Earth. To make the study of lifeforms more manageable, scientists divide them into smaller groups. These groups are organised or 'classified' based on the features, patterns and behaviours that organisms share; for example, if they have fur or scales, smooth leaves or spiky leaves, or lay eggs versus give birth to live young (Figure 5.1.4).

Classification is used by biologists to:

- name new species
- compare characteristics of new species to current or extinct species
- study how organisms are connected or related to each other
- create a universal language for scientists to use that is standard across the globe to share their findings
- explore new understandings of species.

The need for a system

Common names and **scientific names** are crucial for identifying and classifying species in biology. Common names, used by the public, vary across regions and reflect local perspectives. By contrast, scientific names offer a standardised global system, removing any confusion with common names across the globe.

Many living things are known by their common names in different countries, which can become confusing if these names suggest a link between species where none exists. The examples in Table 5.1.1 each use 'bobtail' in their common names, although they belong to very different species.

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

HINT

Scientific names are always written in italics.

TABLE 5.1.1 These animals that have 'bobtail' in the common name are not the same species.

Bobtail lizard

The bobtail lizard is also known as the shingleback skink or stumptail skink. The tail of the shingleback skink (*Tiliqua rugosus*) resembles its head, thus confusing predators.

Bobtail squid

The Atlantic bobtail squid (*Sepiola atlantica*) gets its name from the distinctive shape of its body, specifically its short and rounded back end, which resembles a bobbed tail.

Japanese bobtail cat

Unlike many other cat breeds that have long, flowing tails, the Japanese bobtail cat (*Felis catus*) has a short, often kinked or curved tail.

SC 2 CHECK YOUR UNDERSTANDING

List two reasons why biologists classify species.

SC 3 I can suggest how classification systems are affected by cultural perspectives and world views

World views

The way people view the world, often described as a **world view**, is affected by a range of factors. These include **cultural perspectives**, which inform peoples' thoughts and actions.

Western science is a relatively new world view. Western systems of science seek to understand and explain the world by conducting experiments and collecting measurements. Knowledge is shared through written records and technology. Western science is influenced by elements of Western **culture** and values including individualism (individuals decide what is important to study and publish), objectivity (being unbiased and focusing on facts rather than feelings) and reason (the need to have evidence).

KEY TERMS

world view a way of considering the world in terms of attitudes, values and beliefs

cultural perspective the way that an individual is affected by their environment, as well as social and cultural factors, including race and gender

Western science approaches and ways of scientific working that are derived from European countries

culture a combination of the values, beliefs, language systems, communication and practices that people share

KEY TERMS

ecosystem a system formed by organisms interacting with each other and their non-living surroundings

spiritual importance a sense of connection to a greater force, like nature, the universe or a higher power

Indigenous knowledge systems centre around collective observation, shared experience and continuous experimentation. Knowledge is passed down through generations through oral traditions, cultural practices and other recording methods. Indigenous knowledge systems place a greater importance on the interconnections between people, places and processes, they focus on holistic benefits to the community and environment, and often recognise multiple truths and perspectives.

Cultural perspectives of classification

Throughout the world, people of different cultures have different approaches to classifying living and non-living things commonly found in their environment.

In indigenous knowledge systems, elements of the natural world can be classified based on their roles within the **ecosystem**, physical attributes, cultural significance or **spiritual importance**.

FIGURE 5.1.5 The kangaroo apple is only edible when ripe. Unripe fruit is toxic.

First Nations classification systems

First Nations Australians, for example, have developed intricate classification systems that align with their dietary, environmental, practical and spiritual contexts. Importantly, plants and animals are first classified according to whether they are edible or inedible (such as Figure 5.1.5). Natural elements such as water, celestial (sky and space) bodies, animals and plants may also be classified according to their spiritual meanings, often linked to specific social groups or tribes.

Traditionally, these classification systems have been important when performing tasks such as food gathering and water sourcing, but this knowledge of the land's physical features and seasonal variations is still transmitted across the generations through storytelling, cultural ceremonies and direct observation.

FIGURE 5.1.6 Jamitakari (the wet season) is the best time to collect Kurumpuka (crabs) in the Tiwi calendar.

Classifying seasons

First Nations classification is guided by unique markers and changes in the environment—such as celestial events and the stages of the water, plant and animal cycles and behaviour—that signify when a particular season has started or ended.

Depending on their location, First Nations groups may recognise many seasons. For example, the Tiwi calendar identifies three major seasons and thirteen minor, overlapping seasons (Figure 5.1.6). This is in contrast to the four, fixed seasons defined by Western societies. These environmental cues also trigger seasonal adjustments in practices and behaviours. As for the naming of living things, this often involves providing descriptive markers to enhance understanding of the organism's characteristics and features.

The seasonal classification system used by the Noongar people in the south-west of Western Australia is shown in Table 5.1.2.

TABLE 5.1.2 The seasonal classification system used by the Noongar people of Western Australia

Season	Months	Description	
Bukuru	February, March	Dry season with winds from the east and north. Wattle comes into blossom.	
Djeran	April, May	Cool winds from the south-west. Group fishing takes place at lakes and weirs (inland). Fishing also occurs at estuaries.	
Makuru	June, July	Cold, rainy season with strong winds from the west. Kuljak (black swans) begin moulting, making them unable to fly and easier to hunt.	
Djilba	August, September	Temperature increasing. Activities include collecting roots (meen and djakat), digging out *Platysace cirrosa* tubers from under wandoo (a type of *Eucalyptus* tree), and hunting waitch (emus), quenda (southern brown bandicoot), yonga (kangaroos) and koormul (possums).	
Kambarang	October, November	Warmer days with less rain. *Astroloma* and desert quandong begin fruiting.	
Birak	December, January	Hot and dry season with wind from the east, changing to the south-west in the afternoon. *Banksia* begins to flower and is gathered for nectar.	

Scifile

Emu in the Sky

The Celestial Emu, or Emu in the Sky, is a constellation that can be used as a First Nations classification system by linking its position and visibility in the night sky to the breeding, hatching and nesting seasons of emus. This is then linked to various seasonal and ecological events on Earth throughout the year.

SC 3 CHECK YOUR UNDERSTANDING

Describe ways non-Western cultures may categorise organisms.

Lesson review

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

1 Explain why classification is important for studying biodiversity.

2 Describe how you could classify a newly discovered organism using a classification system.

3 Describe how you would explain the importance of classification to someone unfamiliar with biology.

4 Identify one way organisms may be categorised by First Nations cultures.

5 First Nations peoples have been classifying organisms for thousands of years.

- a Describe ways that First Nations peoples have communicated their understanding of classification.
- b Briefly explain one example of classification that has been communicated.
- c Explain how scientists may benefit from knowledge that First Nations Australians have about classification.

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 by 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.

SC 3: I can evaluate methods used to sort organisms.

Background

Many people consider the items in salads to be vegetables, but some of them are actually fruit, such as tomatoes (Figure 5.2.1). Fruits and vegetables are 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?
aggregate fruit	many small fruits, or fruitlets, joined together to make a large fruit	fruit
berry	fleshy, edible fruit that has seeds embedded within its flesh	fruit
legume	also known as a pod; opens at the side to release seeds	fruit
simple fruit	fruit formed around a hard stone or pit, which contains a seed	fruit
bulb	grows in clusters or layers just below the soil surface with a leafy shoot above	vegetable
leaf	an edible leaf	vegetable
root	usually a long or round root	vegetable
stem	edible stem or stalk of the plant	vegetable
tuber	grows underground, attached to the root of the plant	vegetable

FIGURE 5.2.1 In biology, tomatoes are classified as a simple fruit because the seeds are contained within the edible part of the plant.

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.

HINTS

Refer to Table 5.2.1 that describes the features of different types of fruits and vegetables.

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 5.2.2 Be sure to observe the outside and inside features of the food.

Aim

To investigate the similarities and differences between fruits and vegetables

Materials

- 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 5.2.2.

2 Choose two food items that have been supplied and observe them carefully. Write down their features.

3 Use Table 5.2.1 to classify these foods.

4 Create your own table to record the features and classification of the food 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.

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.

Evaluation

Suggest two ways this investigation was challenging and what could be done to improve it.

5.3 Introduction to keys for identification

Lesson overview

Scientists organise things according to their similarities and differences. Keys for classifying living things include a series of questions or statements about the features of organisms. **Classification keys** are used to identify the group that an object or a living thing belongs to. 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 5.3.1). 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.

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.

SC 3: I can evaluate the strength of dichotomous keys and suggest ways to make them more effective.

KEY TERM

classification key a tool that helps scientists classify organisms based on their observations and descriptions

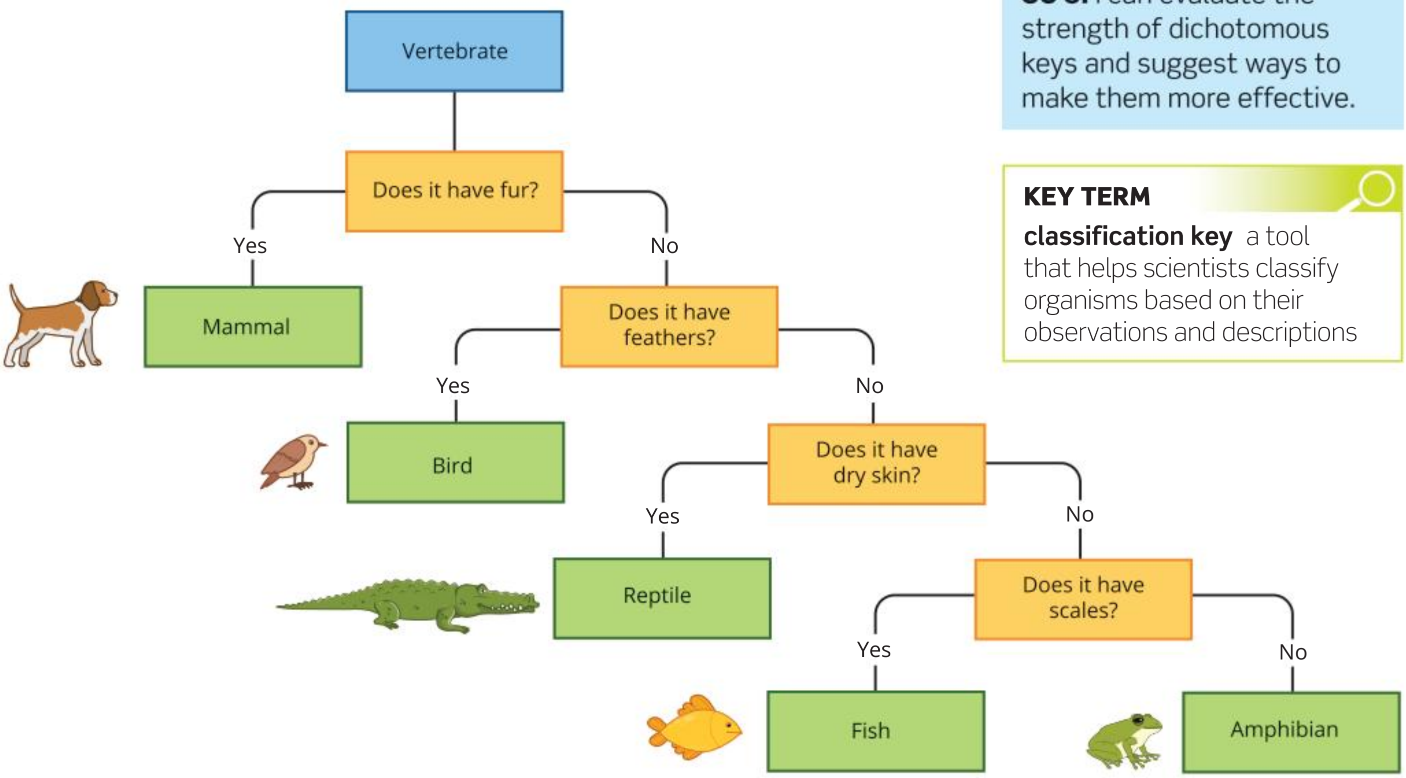


FIGURE 5.3.1 A dichotomous key used to classify animals with backbones (vertebrates)

SC 1 I can use a branching dichotomous key to identify objects or organisms

Classification is used to group things so that relationships and connections between them can be used for clear identification. Scientists use keys to assist with the organisation of objects and organisms and can be used to identify new additions to the group.

KEY TERM

dichotomous key a key with two choices at each stage

Scifile

Classifying butterflies

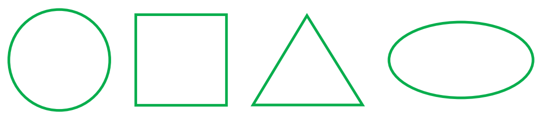
With a dichotomous key, you can identify butterfly species by looking at wing patterns and colours. This tool helps entomologists (scientists who study insects) understand butterfly diversity and track changes in populations.

Although millions of different species of organisms have been identified by scientists, many more are likely to still 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. Some dichotomous keys are based on structural features that do not change, such as number of legs or shape.

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. The following simple example shows how these two types of keys: table and branching, can be used to identify different shapes.

A table dichotomous key

The four shapes in Figure 5.3.2 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 5.3.2 A table dichotomous key used to classify shapes

A branching dichotomous key

A branching flow chart key as seen in Figure 5.3.3 is read by starting at the top and working through the descriptions until you can classify the shape.

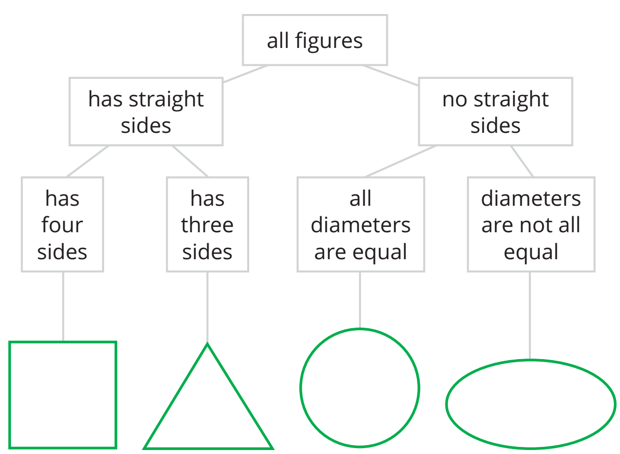


FIGURE 5.3.3 A branching dichotomous key used to classify shapes

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 this branching key (Figure 5.3.4) designed to identify types of 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. The description allows the item to be identified as a rollerblade.

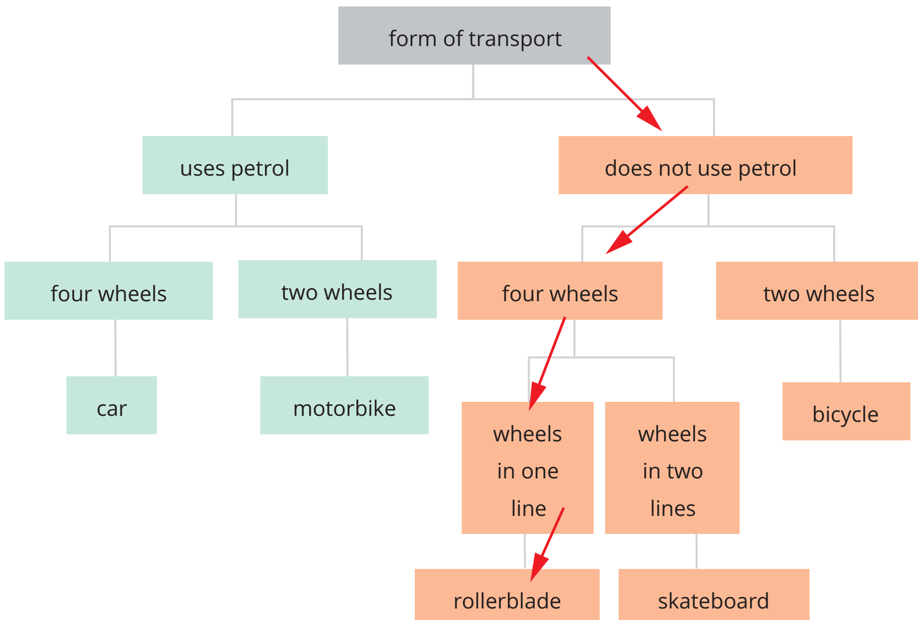


FIGURE 5.3.4 An example of how a branching dichotomous key can be used to classify rollerblades

SC 1 CHECK YOUR UNDERSTANDING

Explain 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. For example, in a key used to classify food, the first question could be whether the food is a fruit, and then the later question could be about the fruit's features such as colour and shape.

The word 'dichotomous' means divided into two parts. Branching keys and table keys always present two choices based on the key characteristics of the object or organism in each step. By selecting the correct choice at each stage, the name or grouping of the object or organism can be identified at the end. Both qualitative observations of physical features, such as how the object or organism looks, its shape and what colour it is, and quantitative factors, such as the number of legs, number of leaf veins and number of eyes, should be considered.

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 figure out what plant you are looking at. This can help you take better care of your garden and even contribute to local biodiversity by planting native species.

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 moving to the next set of options.

Consider the table key for identifying animals that live in and around soil (Table 5.3.1). A creature was found to have 16 pairs of legs and no antennae.

TABLE 5.3.1 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.

So, the animal is a centipede.

SC 2 CHECK YOUR UNDERSTANDING

Describe what a table dichotomous key looks like and how it is used.

SC 3 I can evaluate the strength of dichotomous keys and suggest ways to make them more effective

Effective dichotomous keys

Developing dichotomous keys can be challenging and it is important that they can be used effectively to identify things.

Features of good dichotomous keys include:

- a clear and straightforward **dichotomous question**; for example, 'has a red beak' or 'has an orange beak'
- a focus on features of the organism that are unlikely to change over time; for example, fur colour may change throughout the seasons of the year, but the number of legs of an organism do not. Leg number would be a better choice for a key
- a criterion that is not subjective; for example, 'tall' or 'short' is a subjective criterion, but 'larger than 100 cm' and 'smaller than 100 cm' is an objective and measurable criterion.

KEY TERM

dichotomous question a question that limits responses to only two possible answers

HINT

Terminology tip

Subjective data is based on personal views, feelings and experiences. Objective data is based on measurable facts and information that is free from personal bias.

SkillBuilder

Dichotomous questions

Dichotomous questions are questions that have only two possible answers. They are used in dichotomous keys, which can be used to classify or identify organisms.

Method for writing good dichotomous questions

1. Decide on the characteristic, feature or behaviour that will reveal a difference (distinguish) between the organisms being classified or identified.
2. Choose a characteristic that is easy to observe or can be measured, such as number of legs, length of body compared to head, or shape of wing.
3. Avoid characteristics that are not easy to observe or measured, or that can change on an animal or a plant depending on the age of the organism or the time of year, such as size and colour.
4. Draft a question about that characteristic that has either a 'yes or no' answer, or has only two possible answers.
5. Try to use a question that does not just separate one organism from all the others. (However, these types of questions can be used later in the key when you only have a few organisms to identify.)

For example, Stella was developing a key to distinguish between breeds of cat. She wanted to use the appearance of the cats.
Three questions that she chose to use were:

- Does the cat have more than one colour on its coat?
- Does the cat have stripes of different colours?
- Is the head of the cat a different colour to most of the rest of the body?

Worked example

Dichotomous questions

Problem

Which of the following are dichotomous questions that can be used in keys? Explain your reasoning.

a. How many legs does the animal have?

b. Does the organism have six legs?

c. Is the plant big?

d. Does the animal like eating fish?

e. Does the plant have leaves that have smooth edges?

Solution

Thinking	Working
a How many legs does the animal have?	
Are there only two possible answers?	No, the answer can be a range of different numbers, so this is not a valid question for a dichotomous key.
b Does the organism have six legs?	
Are there only two possible answers?	Yes, it either has six legs or does not have six legs.
Is the question clear?	Yes
Can you observe the answer to the question?	Yes, you can count the exact number of legs.
Is this a valid dichotomous question	Yes
c Is the plant big?	
Are there only two possible answers?	Yes, it is either big or not big.
Is the question clear?	No, the description 'big' is not clearly defined, so this is not a valid question for a dichotomous key.
d Does the animal like eating fish?	
Are there only two possible answers?	Yes, it is either likes eating fish or does not like eating fish.
Is the question clear?	Yes
Can you observe the answer to the question?	No, you do not know if the animal 'likes' eating fish (you cannot ask them!), so this is not a valid question for a dichotomous key.
e Does the plant have leaves that have smooth edges?	
Are there only two possible answers?	Yes, this is relatively easy to judge.
Is the question clear?	Yes
Can you observe the answer to the question?	Yes
Is this a valid dichotomous question	Yes

Try yourself

Consider the following questions and analyse whether they are suitable for use in a dichotomous key. To be a suitable dichotomous question, it must have only two possible answers and be clear.

a Does the tree have lots of leaves?

b Does the animal have four legs?

c Where does the animal live?

d Does the insect have more than one pair of wings?

SC 3 CHECK YOUR UNDERSTANDING

Explain what a dichotomous question is.

Lesson review

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

1. Explain 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.

5.4 Creating dichotomous keys

Introduction

Organisms are grouped according to the similarities and differences to make it easier to classify and identify them. The easiest way to classify things is to create keys to organise them using specific criteria. The tool that biologists use is the dichotomous key. These keys can be branching keys or table keys, although there are some other types of keys less commonly used.

In this practical investigation, you will create dichotomous keys to group objects and organisms based on their similarities and differences.

Learning intention

To be able to create a dichotomous key to identify living and non-living objects

Success criteria

SC 1: I can write suitable questions for use in a dichotomous key.

SC 2: I can create and use a branching dichotomous key.

SC 3: I can create and use a table dichotomous key.

KEY TERMS

taxonomy the science of classifying and naming things

taxonomist a scientist who specialises in classifying and naming things

Background

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. You may have seen books or apps called 'field guides' that describe different types of organisms (such as birds, reptiles, insects and plants). A dichotomous key is a tool used to classify organisms (Figure 5.4.1); it has two choices at each step (e.g. serrated leaves or smooth leaves).

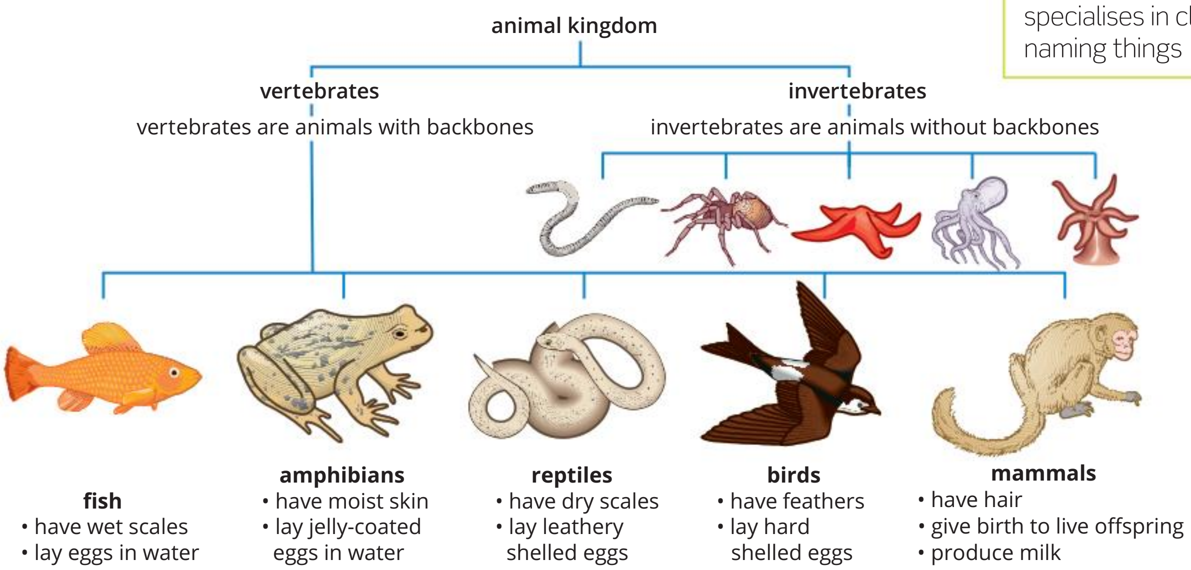


FIGURE 5.4.1 A branching dichotomous key used to classify animals

Aim

To create keys that can be used to identify types of pasta and types of leaves

Materials

Part A

- various samples of pasta
- paper and pencils

Part B

- 10 different leaves
- large sheet of paper
- pencil
- marker pen
- camera (optional)
- field guidebooks or app for Australian garden and native plants (optional)

SAFETY NOTE

- Do not taste or eat the food items.

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: Types of pasta

HINT

Look for differences in shape and size. A table will help to organise the similarities and differences so that similar pasta types will be more obvious.

1 Describe each type of pasta, focusing on differences between the types of pasta. Think about how you can present your observations.

2 Create some dichotomous questions that can be used to distinguish between the types of pasta.

3 Use the differences to construct a table dichotomous key.

Part B: Identifying leaves

1 Collect 10 leaves from different healthy plants. Take a single leaf without damaging the main plant. If you have a camera, photograph each plant and your leaf sample.

2 In the classroom, trace an outline of each leaf onto paper.

3 Write labels A–J inside the 10 leaf outlines. Use the marker pen to write matching letter codes on each leaf. For plants that you know, also write the plant's name inside the shape.

4 On the paper, make a list of features that could be used to sort your leaves into different groups.

5 On your list, highlight the strongest features for classifying the leaves (such as shape, arrangement of veins, leaf edge characteristics).

6 Select one feature and use it to sort the leaves into two groups (such as round leaves/non-round leaves). Record these two options as the first step in your dichotomous key.

7 Working with one group of leaves at a time, select a different feature and use it to sort that group of leaves. Record these two options as the second step in your dichotomous key.

8 Continue selecting features and sorting leaves until you reach an individual leaf. Record each step in your dichotomous key.

9 When your key takes you to an individual leaf, record the leaf on the key with its letter code (A–J).

10 Repeat steps 6–9 until you have classified all the leaves that you collected.

Results

Review your dichotomous key and, if required, redraw a final version.

Evaluation

Ask other students to try classifying leaves or pasta using your keys and use other students' keys.

1 Describe any improvements that you could make to the keys to enable more effective classification.

2 Identify strengths and weaknesses of dichotomous keys.

HINTS

Identification keys work best if they use strong features that stay the same over time and are easily observed.

Remember to use two opposing choices at each step (such as pointed leaf tip or rounded leaf tip).

Quantitative features (features you can measure) are stronger to use than qualitative descriptions. For example, 'mature leaf, 2–3 cm length', is better than 'older, long leaf.'

5.5 Linnaean classification system

Learning intention

To understand the Linnaean hierarchical classification system and its related naming conventions

Success criteria

SC 1: I can list the levels in the Linnaean hierarchical classification system in order.

SC 2: I can classify an organism's kingdom, phylum and class using the Linnaean hierarchical classification system.

SC 3: I can identify the genus name and species name in an organism's scientific name.

Lesson overview

Historically, humans have always tried to make sense of things around them, especially living things that they share their environment with. Human survival was dependent on being able to distinguish between predator and prey, and between poisonous and non-poisonous. People sorted the things around them using characteristics such as colour and size of teeth, and by observing other animals' feeding habits. This 'classification' was based on trial and error, and stories passed through the generations so that people learnt from others' mistakes.

In this lesson, you will learn about how philosophers and scientists in the past created naming systems that were more specific and enabled the enormous diversity of life on Earth to be classified scientifically and more precisely.

SC 1 I can list the levels in the Linnaean hierarchical classification system in order

Development of classification systems

Many ancient philosophers developed their own ways of classifying the living things around them. One of those philosophers was Aristotle, a Greek who lived from 384 to 322 BCE. He attended Plato's Academy in Athens and studied medicine, philosophy and astronomy and 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.

HINT

Terminology tip

A naturalist is a person who studies the natural world.

A philosopher is a person who studies philosophy, which in the past included physics, mathematics, biology and chemistry.

Carl Linnaeus and hierarchies

Later, a Swedish scientist called Carl Linnaeus, who lived from 1707 to 1778, developed a more specific classification system using a hierarchy (Figure 5.5.1). The highest level of the hierarchy originally divided living things into animals and plants.

FIGURE 5.5.1 Carl Linnaeus

Over time, especially since the invention of microscopes, the characteristics of living things have been observed more closely at the cellular level and there are now at least five distinct **kingdoms** recognised today by taxonomists. The smallest and most specific level of classification is the **species**.

KEY TERMS

kingdom the first level of classification of living things

species the last level of classification of living things

The Linnaean hierarchy

In the **Linnaean classification**, organisms can be classified based on specific characteristics that they share. The levels of this hierarchy are kingdom, phylum, class, order, family, genus and species (Figure 5.5.2).

The class of organisms you are most familiar with is mammals. Humans, for example, are classified as mammals because they share key characteristics with other mammals, such as horses and dogs.

Like humans, horses and dogs have fur or hair on their skin and feed their young with milk produced by mammary glands. However, unlike humans, horses and dogs have tails and they have eyes positioned on the sides of their heads.

Primates, including gorillas and monkeys, share more features with humans, such as forward-facing eyes, and belong to the same order. However, monkeys have fewer traits in common with humans and gorillas, so they do not belong to the next hierarchical level, the family.

Although gorillas share more similarities with humans than most other animals, they also have unique features, placing them in their own genus.

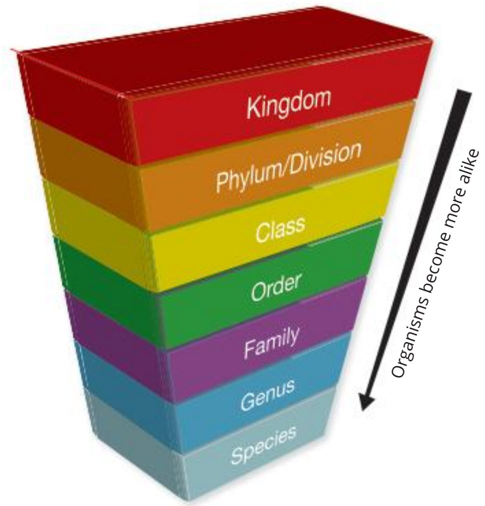


FIGURE 5.5.2 The Linnaean classification system is a hierarchical system with organisms most closely related belonging to the same species.

Modern humans are classified as animals and specifically as *Homo sapiens*, with *sapiens* being the species name (Figure 5.5.3).

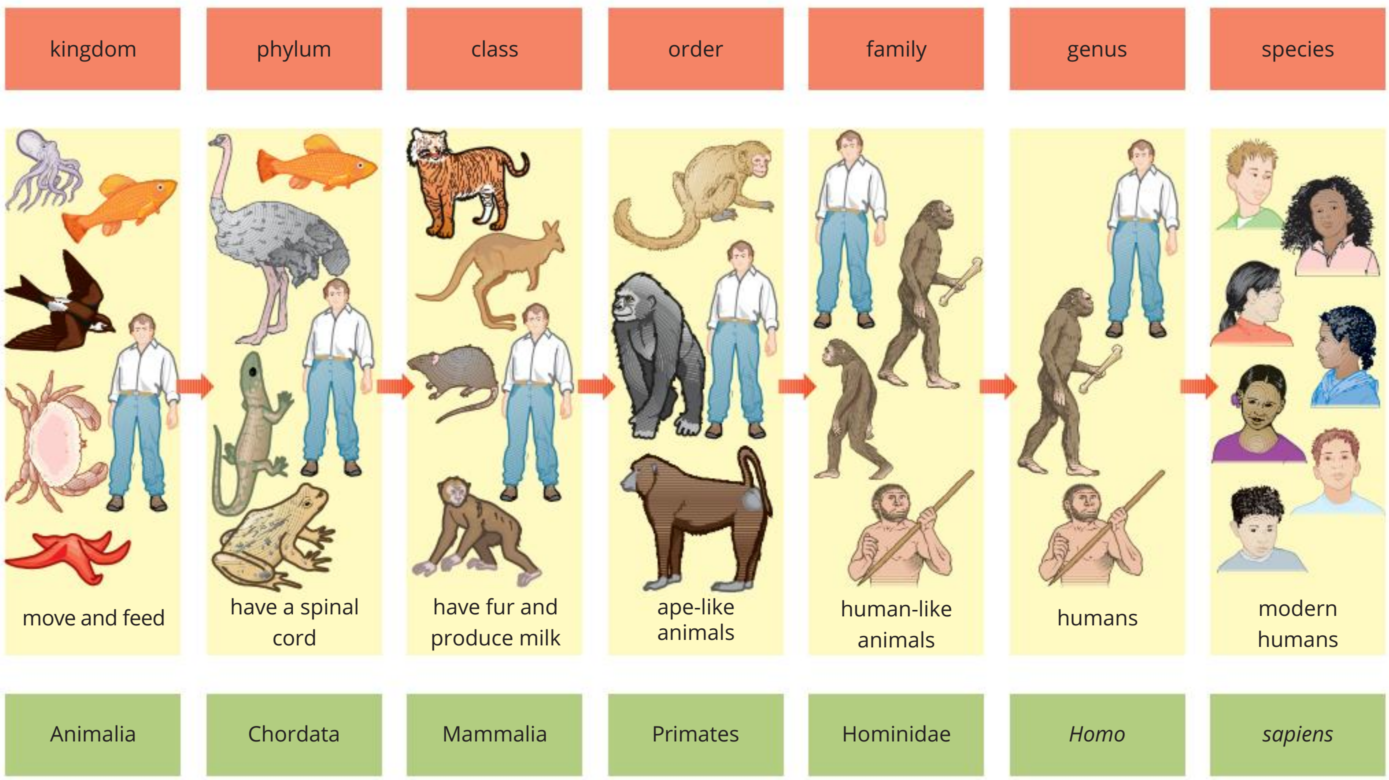


FIGURE 5.5.3 Levels of classification show how much more similar organisms become as they progress through the hierarchy.

SC 1 CHECK YOUR UNDERSTANDING

List the levels of the Linnaean hierarchical classification system from highest to lowest.

KEY TERM

Linnaean classification
a hierarchical system of classifying organisms, aimed at reflecting their evolutionary relationships

SC 2 I can classify an organism's kingdom, phylum and class using the Linnaean hierarchical classification system

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 separated into Eubacteria and Archaebacteria, thus creating a six-kingdom classification model (Figure 5.5.4), which is now widely used.

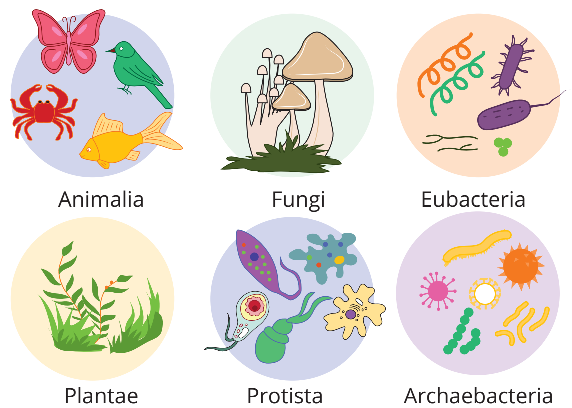


FIGURE 5.5.4 The six kingdoms Animalia, Fungi, Eubacteria, Plantae, Protista and Archaebacteria

Classification models have evolved as scientists gained access to more powerful microscopes, allowing for a deeper understanding of both the structure and behaviour of organisms. For example, it was not until the 1990s that microbiologists had the technology to distinguish key differences between bacteria, leading to the classification of Archaebacteria and Eubacteria into separate kingdoms.

Phyla

Each of the kingdoms is divided into phyla (singular form: **phylum**). For example, animals that have backbones such as humans, snakes, birds and fish are classified in the **Chordata** phyla. Other phyla are the annelids or round worms, the arthropods that include insects and spiders, and the molluscs such as crabs, snails and squid.

KEY TERMS

phylum the second level of classification of living things, below kingdom and above class

Chordata the phylum that includes animals with backbones

class the third level of classification of living things, below phylum and above order

Classes

Organisms belonging to the same **class** have more features in common than those belonging to the same phylum. For example, the phylum Chordata within the animal kingdom, is made up of animals that have backbones. This phylum is then subdivided into classes based on even more specific characteristics, including the type of skin they have. For example, the class of reptiles have dry scaly skin, whereas mammals have fur.

SCIENCE IN SOCIETY

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, helping conservationists monitor their populations and take action to protect them (Figure 5.5.5).

FIGURE 5.5.5 Accurate classification of wildlife, like this Tasmanian devil, is an important part of wildlife conservation.

SC 2 CHECK YOUR UNDERSTANDING

There are many different types of reptiles that are native to Australia.

a State the correct name for the kingdom that reptiles belong to.
b State the phylum that reptiles belong to, giving a reason for your answer.

SC 3	I can identify the genus name and species name in an organism's scientific name

Scientific names

Scientific names are very useful to biologists as they enable them to know exactly what the organism looks like and how it is related to other similar organisms. There are often many 'common names' for living things used by people from different countries and cultures. Providing a scientific name enables the names to be recognised world-wide (Figure 5.5.6).

Scientific names use a binomial system. Binomial means that two names are used, the genus and the species names. This system of naming and classification was developed in the 1700s in Europe, when Latin was the language used by the most well-educated people who developed the system. This system is used internationally even though, nowadays, most people do not speak Latin.

FIGURE 5.5.6 The common name for this mammal is the eastern grey kangaroo. The scientific name is *Macropus giganteus*.

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**. The genus name always begins with a capital letter.

KEY TERMS

genus the second last level of classification of living things, below family and above species
order the fourth level of classification of living things, below class and above family
family the fifth level of classification of living things, below order and above genus

FIGURE 5.5.7 The grey iron bark has the scientific name *Eucalyptus* (genus) *paniculate* (species).

Species

The species name of an organism is unique to it. No other species within the genus has the exact same characteristics. New species are found regularly and are given a name that is not given to any other organism. The species name is often a Latin word that descries its characteristics, the place the species was found, or in honour of a person. The species name always begins with a lower-case letter, and this distinguishes it from any other level of classification (Figure 5.5.7).

How to write a scientific name

When scientific names are typed, they are in italics, with the genus first then the species, like this: *Genus species*. For example, the scientific name for humans is *Homo sapiens*. If the name is written by hand, it should be underlined (<u>Homo sapiens</u>). Examples of binomial scientific names with commonly used names are shown in Table 5.5.1.

TABLE 5.5.1 Examples of commonly used names for organisms followed by their scientific names

Humboldt penguin—*Spheniscus humboldtii*

Lacy tree fern—*Cyathea cooperi*

Funnel web spider—*Atrax robustus*

E. coli bacteria—*Escherichia coli*

SkillBuilder

Scientific names

Classification systems have different levels. The further you go down through the levels, the fewer living things there are at each level.

The seven levels of classification for living things (organisms) are:

Level of classification	Example
Kingdom	Animalia
Phylum	Chordata (animals with backbones)
Class	Mammalia (animals with backbones and females produce milk)
Order	Diprotodontia (mammals with two large front teeth and two toes fused together)
Family	Macropodidae (*diprotodontia* with no canine teeth and very strong fourth toes)
Genus	*Osphranter* (macropod with long rear feet and strong back legs
Species	*robustus* (Latin for strong/sturdy)

The bottom two levels of classification, the genus and the species, are added together to give the scientific name of the organism.

Note that the genus name starts with a capital letter and the species name starts with a lower-case letter.

The genus and species are usually written in italics.

Naming a species

Identify the genus to which the organism belongs.

1 This is the first word of the name and is written with a capital letter.
2 Identify the species of the organism.
3 This is the second word of the name and is written with a lower-case letter.

For example, Hugo was asked to give the scientific name for humans.

The genus is *Homo* and the species is *sapiens* so the scientific name is *Homo sapiens.*

Scifile

Changing names

As scientists' understanding of the genetics of living things continues to improve, some classifications may change. For example, in the past the red kangaroo had the scientific name *Macropus rufus*. *Macropus* was the genus and *Osphranter* was the subgenus. However, in 2019, *Osphranter* was moved to the genus level. Genetic analysis confirmed the red kangaroos' inclusion in the genus *Osphranter*.

Worked example

Scientific names

Problem

Give the scientific name of the red kangaroo. The kangaroo is in the genus *Osphranter* and the Latin word for red-haired is *rufus*.

Solution

Thinking	Working
1 Identify the genus name.	*Osphranter*
2 Identify the description of the species.	*rufus*
3 Combine the name.	*Osphranter rufus*

Try yourself

In December 2021, scientists at Kings Park in Perth, Western Australia, created the world's first blue kangaroo paw using plant hybridisation techniques. The scientist called the new species 'masquerade'. Kangaroo paws belong to the *Anigozanthos* genus.
Create the scientific name for this new species.

SC 3 CHECK YOUR UNDERSTANDING

Identify the genus and species name of the scientific name for cat, *Felis catus*.

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 smallest to largest.

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 *Homo sapiens*.

5 Explain the benefit of scientific names over common names.

5.6 Levels of classification in the animal kingdom

Lesson overview

It is estimated that more than eight million living things on Earth are part of the animal kingdom. All animals have typical animal cells, and this distinguishes them from other kingdoms. Animals are also multicellular, which means they are made up of many cells. It is thought that the earliest animals existed as far back as 560 million years.

As there are so many animals, it makes sense to divide them into small groups based on similar features. There are nine main phyla of animals.

In this lesson, you will investigate the characteristics that separate the animal kingdom into phyla, and explore the key features of the classes of one of the phyla, chordates.

Learning intention

To describe how the Linnaean system can be used to classify biodiversity in the animal kingdom

Success criteria

SC 1: I can describe the characteristics of nine major animal phyla and give examples of each.

SC 2: I can describe the characteristics of the classes of chordates and state an example of each.

SC 3: I can describe the classification levels of a range of Australian native animal species.

SC 1 I can describe the characteristics of nine major animal phyla and give examples of each

Most people think of well-known living things, such as humans, dogs, cows and elephants, as animals (Figure 5.6.1). Within the animal kingdom, nine major phyla are used to classify biodiversity, ranging from organisms with and without backbones, many limbs and no limbs, and even those with different coloured blood. The common characteristic they share is they are all made up of many animal cells. As cells cannot be seen without a microscope, most animals can be identified as animals because they require oxygen and food, they move and can sense the environment around them.

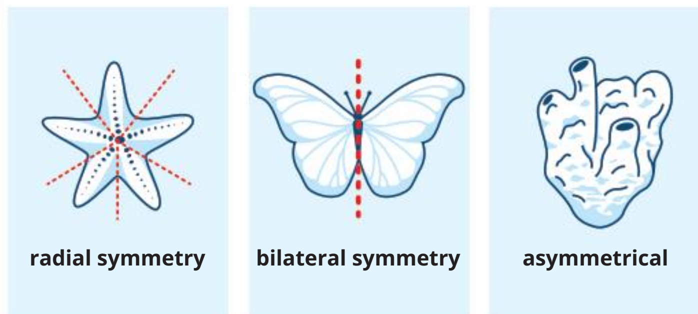
FIGURE 5.6.1 Humans and dogs belong to the phylum Chordata and the class Mammalia.

HINT

Note that the names of the phyla end in -a; for example Annelida. Animals that belong to that phylum can be described as annelids. Animals that belong to the phylum Chordata are called chordates.

The different phyla in the animal kingdom are usually based on the characteristics shown in Table 5.6.1.

TABLE 5.6.1 Characteristics of different phyla

Characteristic	Explanation
Symmetry	Symmetry is the amount of similarity between different sides of the organism. There are two main types of symmetry: • Radial symmetry, where the body parts of an organism are arranged around a central point. • Bilaterial symmetry, where the organism is the same on the left and right sides or top and bottom, like a mirror image. Asymmetry/asymmetrical is where the organism has no symmetry and is an irregular shape. 
Skeleton type	Animals can have an **endoskeleton**, an **exoskeleton**, a **hydroskeleton** or no skeleton.
Additional body features	Animals can have a range of features that assist them to live in different environments. Some examples of these features are legs, gills, fins and suckers.

KEY TERMS

endoskeleton a skeleton inside the body
exoskeleton a skeleton on the outside of the body
hydroskeleton a fluid-filled soft tissue inside the body

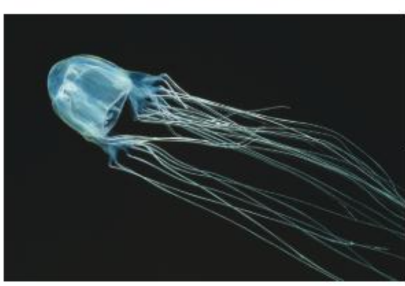
Facts about the main animal phyla

Poriferons

Symmetry: asymmetrical

Skeleton type: no skeleton

Additional features: live in water and are spongy with pores and tubes that filter food and excrete waste; some sponges look like tubes and have an opening at the top that acts as a waste removal system



Cnidarians

Symmetry: radial (all the sides of the cnidaria usually look the same)

Skeleton type: usually have no skeleton

Additional features: have a single body opening to allow food and waste to pass through; live in water and can have stinging cells to poison and capture prey; the box jellyfish (*Chironex fleckeri)* has extremely poisonous venom secreted by the stinging cells on its tentacles

Echinoderms

Symmetry: radial (all the sides usually look the same)

Skeleton type: usually have an endoskeleton with a spiny or leathery outer covering

Additional features: range in colours and have a thick 'armour' on their exterior to protect them from prey, which is left behind when they die; there are two types of echinoderm in this photograph—you can see the orange pigment of a sea star (on the left) and the black spines of a sea urchin (on the right)

Annelids

Symmetry: bilateral

Skeleton type: have a hydroskeleton that works similarly to an endoskeleton but made of a fluid-filled cavity

Additional features: have segments, a tubular gut that stretches along the length of the animal and tiny feet-like projections on either side of the body that assist with movement; Annelida is the phylum that includes segmented worms, such as the earthworm and leaches

Nematodes

Symmetry: bilateral

Skeleton type: many have a hydroskeleton

Additional features: have a long gut that runs the length of the animal, and is more complex in structure and function than annelids; require a watery or damp environment and are found in huge numbers in almost every environment on Earth; some nematodes are parasitic, such as *Ascaris lumbricoides*, which lives in the human intestine and can grow up to 35 cm long

Platyhelminthes

Symmetry: bilateral

Skeleton type: neither an endoskeleton nor an exoskeleton

Additional features: require a watery or damp environment, have one opening for both food and wastes and are flat to allow oxygen to pass into their bodies from the water; Platyhelmintha is the phylum that includes flatworms; they range in size from 1 mm to 15 m in length

Molluscs

Symmetry: bilateral

Skeleton type: either an endoskeleton or an exoskeleton

Additional features: have complex organ systems and highly developed nervous systems; some have a hard shell to cover their soft bodies and a muscular foot to assist movement; Mollusca is a highly diverse phylum that includes snails, slugs, mussels and squid; the protective shell of the snail is clearly observable; the internal skeleton of the squid is a hard white substance often found washed up on beaches

Arthropods
Symmetry: bilateral

Skeleton type: exoskeleton

Additional features: the body is usually divided into three segments and has complex organ systems; legs and antennae are also segmented to enable movement; spiders are just one example of the huge number of arthropods on Earth; there are many other types, including insects, prawns and crabs

Chordates
Symmetry: bilateral

Skeleton type: most have an endoskeleton

Additional features: have a backbone with a nerve chord that runs the length of the vertebral column; birds and mammals are examples of **chordates**

KEY TERM

chordate an animal with a nerve cord running down its back, and an endoskeleton

SC 1 CHECK YOUR UNDERSTANDING

List three major animal phyla and provide one example for each.

SC 2 I can describe the characteristics of the classes of chordates and state an example of each

Animals that have a backbone or vertebrae are classified in the phylum Chordata. Chordates have a nerve cord running down their backs, which gives the phylum its name. Often this cord is protected by a form of backbone made up from small bones called vertebrae. Some chordates, such as sea squirts, do not have vertebrae or a backbone but are also classified under the phylum Chordata because they still have the nerve cord. There are eight classes of chordates:

- Agnatha
- Chondrichthyes
- Osteichthyes
- Amphibia
- Reptilia
- Aves
- Mammalia
- chordates without backbones.

In the past, fish were in a single class but now they are divided into three different classes, Agnatha (jawless fish), Chondrichthyes (cartilaginous fish with jaws), and Osteichthyes (bony fish). The other classes of chordates are Amphibia (amphibians), Reptilia (reptiles), Aves (birds), Mammalia (mammals) and chordates without backbones (Table 5.6.2).

TABLE 5.6.2 The eight classes of chordates

Class	Features	Example
Agnatha	• jawless fish • internal skeleton made of cartilage • gills for obtaining oxygen • soft skin and no scales • fin along their back • mouth is a sucker lined with horny tooth plates • all are parasites	lamprey 
Chondrichthyes	• sharks and rays • skeleton made of cartilage • gills for obtaining oxygen • have jaws and teeth • fins on side of body and on their back (dorsal fin)	stingray 
Osteichthyes	• bony fish • skeleton made of bone • gills for obtaining oxygen • fins on side and back of their bodies • jaws and teeth	barramundi 
Amphibia	• include frogs, toads and salamanders • live in water and on land • breathing through gills, lungs or skin • ectothermic (cold-blooded—rely on external sources to regulate body temperature)	white-lipped tree frog 
Reptilia	• snakes, lizards, crocodiles, turtles and tortoises • dry scaly skin • breathe through lungs • ectothermic	eastern brown snake 
Aves	• birds • feathers cover their skin • breathe through lungs • all have wings but some, such as penguins and emus, do not fly • endothermic (warm-blooded—regulate body temperature by generating their own body heat)	flamingo 

Scifile

Subclasses of mammals

The class of mammals is subdivided into three groups according to their method of reproduction. Placentals, such as humans and whales, develop offspring in the body and give birth when developed young. Monotremes, such as echidnas, lay eggs. Marsupials, such as kangaroos, give birth to underdeveloped babies that grow in a pouch.

Class	Features	Example
Mammalia	• includes animals such as the flying fox, hippopotamus and human • hair or fur covers their skin • breathe through lungs • endothermic • have mammary glands	hippopotamus 
Chordates without backbones	• includes sea squirts and lancelets (small fish-like animals with transparent bodies) • have a nerve cord but not a backbone to protect it • known as invertebrate chordates	sea squirts 

SCIENCE IN SOCIETY

Marine biology

Marine biologists use the Linnaean system to classify and study ocean life (Figure 5.6.2). For example, by classifying different types of coral, scientists can study their interactions with fish and other marine organisms, which is important for protecting coral reefs.

In the Great Barrier Reef, the Linnaean system is used to classify and study the reef's species. This helps researchers monitor the health of the reef and develop strategies to protect it from threats like climate change and pollution.

FIGURE 5.6.2 A marine biologist collecting data to classify organisms

SC 2 CHECK YOUR UNDERSTANDING

List the characteristics that distinguish the class Aves.

SC 3 I can describe the classification levels of a range of Australian native animal species

Biodiversity in Australia

Australian native animals are unique in many ways. Australia is a very large island isolated from all other land masses. This means that the native animals have had to adapt to the various and harsh environments where they live.

Of the class Mammalia, the **monotremes** are only found in Australia and most species of **marsupials** are native to this country. Various other types of animals such as **arthropods**, **cnidarians** and chordates are also unique to Australia.

Many of the kangaroos and wallabies in Australia belong to the same family (macropods) because they have many characteristics in common (Figure 5.6.3). The differences are indicated by the genus and species to which they belong.

KEY TERMS

monotreme a subclass of mammal that lays eggs (e.g. echidna and platypus)
marsupial a subclass of mammal that gives birth to immature young that are suckled in a pouch (e.g. koala, kangaroo and wombat)
arthropod an animal with an exoskeleton and jointed limbs (e.g. crabs and insects)
cnidarian an animal with radial symmetry, one body opening and stinging cells

FIGURE 5.6.3 A rock wallaby in the Northern Territory

Some animals, such as the platypus, have characteristics of several classes of chordates and were originally difficult to classify by early European naturalists. The platypus, for example, has features of mammals, as it is covered in fur, a bird as it has webbed feet like a duck, and a fish as it swims very well in water and lives in water most of the time (Figure 5.6.4). It also lays eggs, just like birds or even reptiles!

FIGURE 5.6.4 The platypus has the scientific name *Ornithorhynchus anatinus*.

By accurately classifying Australia's unique biodiversity, it allows scientists to create more effective conservation strategies to help protect Australia's fauna from threats like habitat destruction and climate change.

The classification of Australian native animal 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	Arachnida	Reptilia
Order	Monotremata	Diprotodontia	Aranaea	Squamata
Family	Tachyglossidae	Macropodidae	Atracidae	Elapidae
Genus	*Tachyglossus*	*Osphranter*	*Atrax*	*Pseudechis*
Species	*aculeatus*	*rufus*	*robustus*	*porphyriacus*
Scientific name	*Tachyglossus aculeatus*	*Osphranter rufus*	*Atrax robustus*	*Pseudechis porphyriacus*

SC 3 CHECK YOUR UNDERSTANDING

Identify the kingdom, phylum and class of the red kangaroo.

Lesson review

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

1 Define the term 'phylum'.

2 List two examples of organisms in:

- **a** phylum Cnidarian
- **b** class Amphibia.

3 Explain the characteristics that define the phylum Chordata.

4 Explain the characteristics that define the class Mammalia.

5 Name three Australian native animal species and provide their classification from the kingdom to the class level.

6 Explain the importance of classifying Australian native animal species.

5.7 Levels of classification in the plant kingdom

Lesson overview

The plant kingdom contains millions of different species. Plants are distinguished from the other kingdoms as they are made up of plant cells, which have cell walls, and they can produce their own food. Plants evolved from forms of green algae more than 400 million years ago.

The plant kingdom is divided into divisions, not phyla. Taxonomists chose to use the term phyla for animals and divisions for plants. Each division is subdivided into classes.

In this lesson, the characteristics that separate the plant kingdom into divisions will be explored, and the key features of the classes will be described.

Learning intention

To understand how the Linnaean system can be used to classify biodiversity in the plant kingdom

Success criteria

SC 1: I can describe the characteristics of some plant divisions and give examples of each.

SC 2: I can describe the characteristics of flowering plants and state an example.

SC 3: I can describe the classification levels of a range of Australian native plant species.

SC 1 I can describe the characteristics of some plant divisions and give examples of each

The plant kingdom is extremely diverse and includes thousands of species of trees, ferns and flowering plants (Figure 5.7.1). They all have one thing in common that makes them unique and different from other kingdoms—they can make their own food by harnessing the energy from the Sun by the process of **photosynthesis**. Plants absorb carbon dioxide, water and sunlight to produce sugars and oxygen. This makes them essential to all other life on Earth.

FIGURE 5.7.1 The plant kingdom includes organisms such as trees, ferns and mosses.

Plant divisions

The plant kingdom is split into **divisions** according to their method of reproduction and the level of organisation of their transport systems. Plant transport systems are responsible for the transfer of water and nutrients throughout the plant.

Three of the plant divisions are considered here (Figure 5.7.2). They are:

- mosses and liverworts
- ferns
- seed-producing plants.

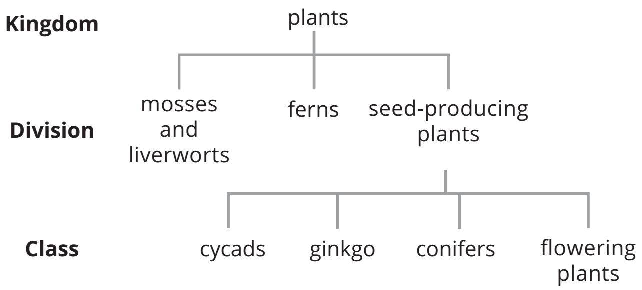


FIGURE 5.7.2 Three of the plant divisions

KEY TERMS

photosynthesis the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from sunlight

division the level below kingdom in the classification of plants

These three plant divisions are explored in more detail here.

Mosses and liverworts

Mosses and liverworts are small simple plants with no roots or flowers. They survive by absorbing water from their environment. *Marchantia polymorpha*, also known as the common liverwort, is found all around the world, especially near shaded pools of water.

Ferns

Ferns have true root systems, stems and leaves that allow the plant to take in and distribute water and nutrients. Ferns form some of the oldest known plant fossils. Australia has tree ferns that belong to a family with origins of over 300 million years ago.

Seed-producing plants

Seed-producing plants are some of the most complex plants in the world. They can use their reproductive systems to make seeds to grow new plants. Some seed-producing plants can produce flowers to assist in **pollination**. Examples of seed-producing plants are cycads, ginkgos, **conifers** and flowering plants.

KEY TERMS

pollination the transfer of pollen from anther to stigma

conifer a plant that bears seeds on cones and has male and female cones on the same tree

SC 1 CHECK YOUR UNDERSTANDING

List three major plant divisions.

SC 2 I can describe the characteristics of flowering plants and state an example

Scifile

Buzzing pollinators

Bees are important pollinators of flowering plants. They cause the plant to vibrate, and the pollen is released. Bees carry pollen to other flowers and deposit it there.

Flowering plants

Flowering plants have complex leaves, stems and roots, as well as various types of flowers that contain the reproductive parts of the plant. There are many different shapes and colours of flowers. These attract certain insects for pollination. Smaller examples of flowering plants, such as grasses, rely on the wind to carry the pollen to other plants.

Flowering plants are seed-producing plants that have flowers and fruit. Their method of reproduction is what distinguishes them from other plants, using fruit to spread their seeds. The male part of the flower is the stamen and produces the pollen that is gathered by insects or dispersed by the wind for pollination. The female part is the ovary (Figure 5.7.3). When the ovary is fertilised, it becomes a fruit and encloses the growing seed. Animals eat the fruit and then spread the seeds so that new plants grow.

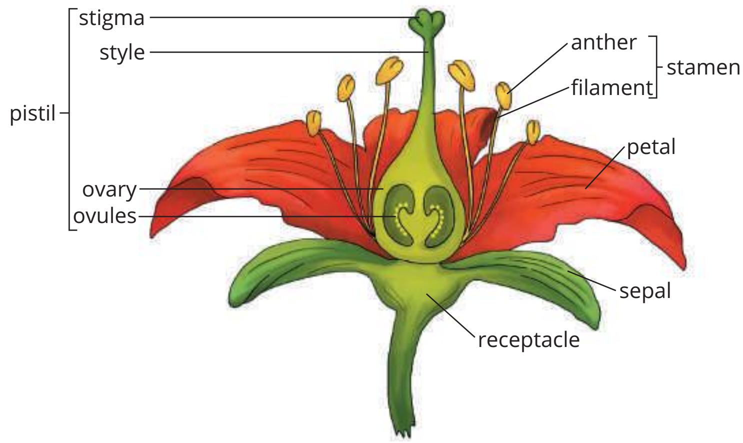


FIGURE 5.7.3 The main parts of a flower are the ovary and ovules, which are part of the female section (the pistil), while pollen is produced in the male section (the stamen).

Examples of flowering plants

Humans rely on flowering plants for food, or to feed the animals that they eat. Table 5.7.1 shows some types of flowering plants. They also provide medicines, timber, dyes, flavours and fragrances.

TABLE 5.7.1 Examples of flowering plants

A rarely seen flower	A flowering plant with edible fruit	Flowers that people travel to see
		
The corpse flower, or *Titan arum*, smells like dead flesh and only blooms for 48 hours after taking years to bloom.	Orange trees provide fruit rich in vitamin C. There are more than 400 varieties of oranges grown worldwide.	Japanese cherry blossom is a tourist attraction in Japan as it blooms in March and April.

SC 2 CHECK YOUR UNDERSTANDING

Identify a key characteristic of flowering plants.

FIGURE 5.7.4 The bark of the blackwood (*Acacia melanoxylon*) is used in traditional medicine as a mild sedative or to soothe indigestion or rheumatism.

FIGURE 5.7.5 Male cones (top) of the Wollemi pine grow lower in the tree than female cones (bottom).

SC 3 I can describe the classification levels of a range of Australian native plant species

Australian native plants, like the country's unique wildlife, have adapted to survive in harsh environments, often with very little water.

For thousands of years, First Nations peoples have relied on native plants for food, medicine (Figure 5.7.4), tool-making materials, and even as a means of locating water. These plants also play a crucial role in providing habitats and food for native animals.

While all native plants have common names, they are also classified using scientific names. The classification system for plants differs slightly from that of other living organisms, following this hierarchy: kingdom, division, class, order, family, genus and species. Many eucalypts, for example, share the same kingdom, division, class, order, family, and even genus, as they exhibit numerous common traits. Their differences are primarily distinguished at the species level.

Well-known examples of Australian native plants are conifers and eucalypts.

Australian conifers

A conifer bears seeds on cones and has male and female cones on the same tree. There are many types of Australian conifers, including the Huon pine (*Lagarastrobos franklinii*) and the Wollemi pine (*Wollemia nobilis*).

The Wollemi pine produces female cones and male cones on the same tree (Figure 5.7.5). The seeds are protected inside the cone until they are ready to be released and dispersed. The seeds have small thin wings, and they rely on the wind for dispersal.

Wollemi pine

Kingdom: Plantae
Division: Pinophyta (conifer)
Class: Pinopsida
Order: Araucariales
Family: Araucariaceae
Genus: *Wollemia*
Species: *nobilis*
Scientific name: *Wollemia nobilis*

Australian eucalypts

Eucalypts are flowering plants. There are more than 700 species, and they make up more than two-thirds of Australian forests. They add a layer of bark to their trunk as they grow, and they are characterised by the shedding of the outer layer. They are adapted to fire and some need the heat for their seeds to open. The fruit is woody and is often referred to as a 'gumnut' (Figure 5.7.6).

FIGURE 5.7.6 Eucalypts produce fruit known as gumnuts.

Australian grey ironbark

Kingdom: Plantae
Division: Angiosperms (flowering plants)
Class: Dicotyledons
Order: Myrtales
Family: Myrtaceae
Genus: *Eucalyptus*
Species: *paniculata*
Scientific name: *Eucalyptus paniculata*

SC 3 CHECK YOUR UNDERSTANDING

Identify the kingdom, division and class of the Australian grey ironbark.

Lesson review

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

1 Define photosynthesis.

2 Explain the significance of flowers in the reproduction of flowering plants.

3 Name two Australian native plant species and provide their classification from the kingdom to the class level.

4 Describe how you would classify a newly discovered plant into one of the major plant divisions.

5 The Huon pine (*Lagarastrobos franklinii*) and the Wollemi pine *(Wollemia nobilis)* are both examples of Australian conifers. Outline characteristics that would help identify these two plants as separate conifer varieties.

5.8 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 of chordate.

SC 2: I can create a dichotomous key that will enable the classification of familiar and unfamiliar animals into classes of chordates.

SC 3: I can evaluate the strength of a dichotomous key used for classification and suggest improvements.

Introduction

You have learnt that organisms are grouped according to their similarities and differences so that it easier to classify and identify them. The tool that biologists use is the dichotomous key, which is created using specific criteria. Once the keys are developed, they can be used to classify unfamiliar or new species of organisms.

In this practical investigation, you will create branching or table dichotomous keys to group animals into the classes 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 are Amphibia (amphibians), Reptilia (reptiles), Aves (birds), Mammalia (mammals) and chordates without backbones.

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 that work by the process of elimination. They can be in the form of a branching flow chart, where the user starts at the top of the flow chart and tracks down through the questions until the organism is identified or classified.

Identifying and classifying

'Identify' means that you can name the organisms (specimens) that you are considering; for example, birds or species of *Eucalyptus* trees in a forest.

'Classify' means that you can identify the group the specimens belong to; for example, identifying whether animals are reptiles, amphibians, mammals, birds or fish, or identifying 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 that 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 5.8.1, which is used to classify plants. Note that it is easier to always have the 'yes' branches on one side and the 'no' branches of the other side.

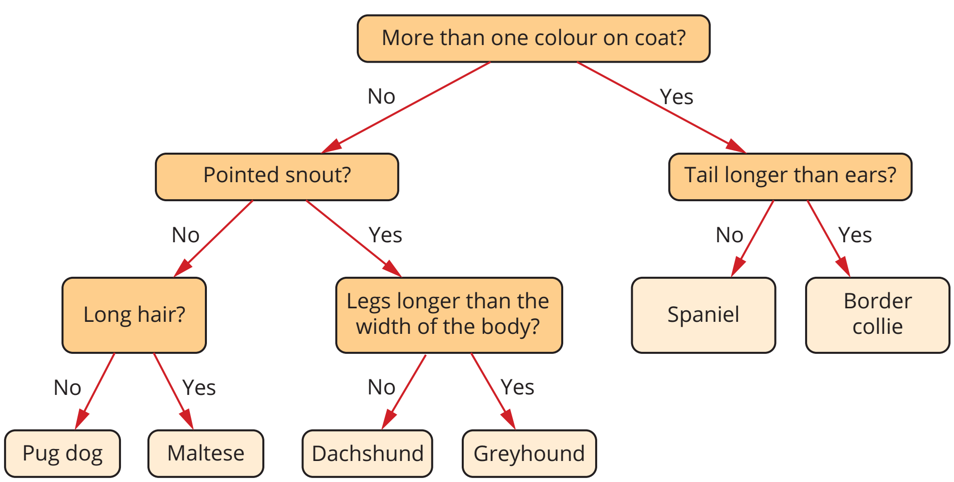


FIGURE 5.8.1 Laila's key

Method 2: Only the answers to each dichotomous question are written on the branch, as shown in Figure 5.8.2, which is used to classify fruit.

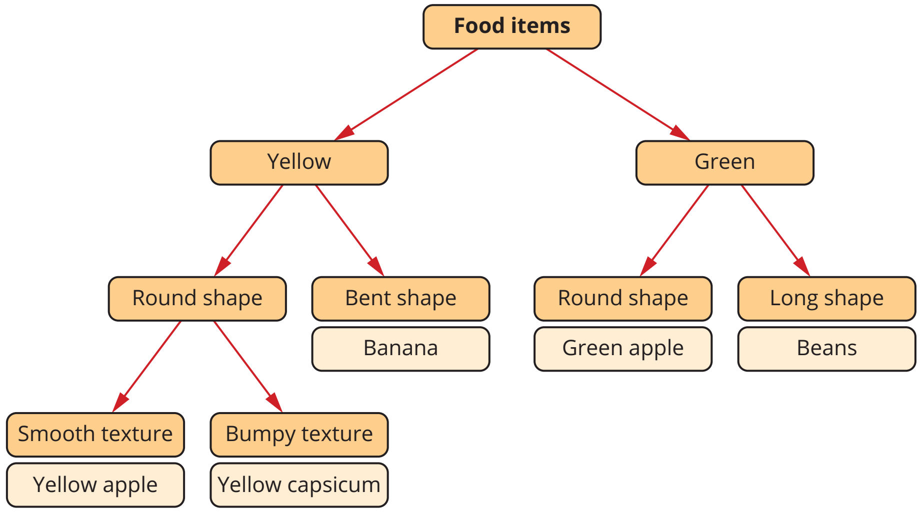


FIGURE 5.8.2 Kai's key

SkillBuilder

Developing table dichotomous keys

Dichotomous keys can be used to classify or identify organisms that work by the process of elimination. They can be 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 you 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 with 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.

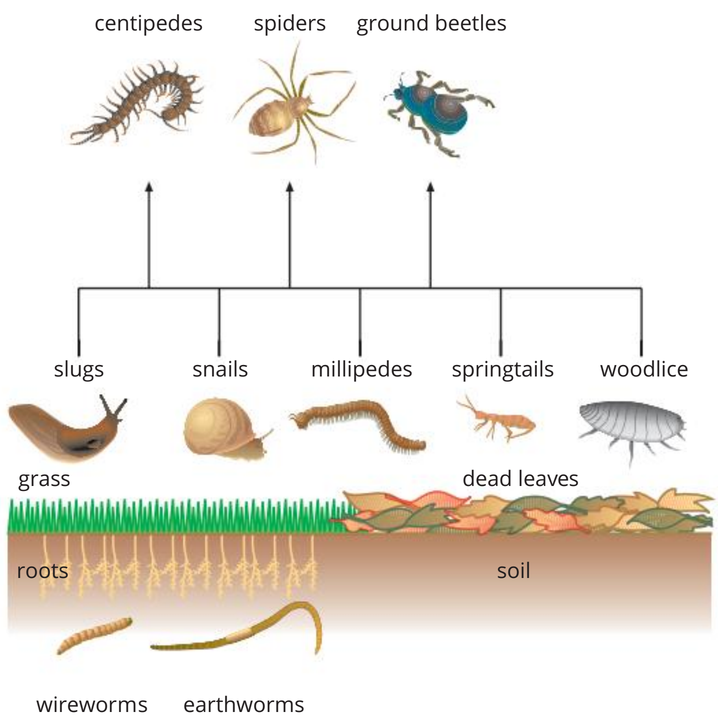
10 Test your key (or get someone else to test it) and make changes to the questions if required.

HINT

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 the 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 beetles
	8b No tail	springtails
9	9a Two body segments	spider
	9b More than two body segments	woodlice

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
- butchers 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 butchers 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.

Evaluation

1 Ask other students to try using your key.

2 Classify an unfamiliar animal using your key.

3 Discuss any improvements that you could make to the key to enable more effective classification.

5.9 Fieldwork as a part of science inquiry

Learning intention

To understand how scientists use fieldwork to collect data

Success criteria

SC 1: I can describe methods that scientists use to observe and identify organisms in the field.

SC 2: I can explain how scientists reduce their impact on organisms and the environment during fieldwork.

SC 3: I can analyse ethical and cultural considerations in conducting fieldwork.

KEY TERM

fieldwork a practical investigation performed mainly outside in nature

Scifile

Wildlife tracking

Scientists use fieldwork to track wildlife populations by observing animal tracks, droppings, and other signs. This data helps them understand animal behaviours and habitats, contributing to conservation efforts and protecting endangered species.

Lesson overview

Scientists ask questions and gather data to find answers. Biologists gather much of their data during fieldwork. Fieldwork involves making observations in the environment that the scientist is interested in. There are many techniques used in fieldwork, alongside safety considerations and ethical behaviour that limits the disruption caused to the ecosystem that is being observed and measured.

In this lesson, the observation techniques used in fieldwork will be discussed. Ethical and cultural considerations, including reducing the impact on ecosystems during fieldwork will also be presented.

SC 1 I can describe methods that scientists use to observe and identify organisms in the field

Scientists who study the environment and living organisms must often work outside the laboratory; that is, in the field. **Fieldwork** involves making observations and collecting data that can be analysed later to help answer scientific questions. Observations must be accurate and precise so that important details are not missed; in classification, for example, such details could be vital for the correct identification of species.

Observations are made in many ways. Scientists make notes about what they observe and any measurements they take (Figure 5.9.1). For example, if they are studying the types of organisms that live in a specific environment, they may record the air temperature, humidity, light intensity and soil type. When recording details about the structure and features of organisms, scientists make sketches and take photographs in addition to their notes and measurements. This enables them to compare observations from previous studies and use keys to identify the organisms observed.

FIGURE 5.9.1 A scientist taking a survey of a coral reef

Recording data

Methods for recording data in the field include:

- making notes
- sketching organisms to scale
- taking photos
- sampling an area
- individual measurements (Figure 5.9.2)
- using existing data, such as observations and scientific journals, to identify organisms
- using dichotomous keys to identify organisms.

FIGURE 5.9.2 Taking measurements is an important part of analysing environments.

SC 1 CHECK YOUR UNDERSTANDING

List two methods that can be used to record data in the field.

SC 2 I can explain how scientists reduce their impact on organisms and the environment during fieldwork

When scientists work in the field, they need to minimise their impact on the environment (Figure 5.9.3). The harmful impacts of fieldwork include any activities that pollute or damage the environment or disturb local wildlife. For example, car tyres and shoes can damage the soil and vegetation and transmit diseases.

FIGURE 5.9.3 Scientists must reduce their impact on the environment when working in the field.

To minimise the **ecological** impact during fieldwork, consider these straightforward practices described in Table 5.9.1.

KEY TERM

ecological a description of something that relates to ecosystems or interactions between living things and their environment

TABLE 5.9.1 Ecological impacts and minimisation strategies

Potential impact	Minimisation strategy
Introducing new organisms from a foreign area	Before entering the field, especially if you have been on a farm or in a contaminated area, thoroughly wash all shoes and boots.
Damaging plants and soil structure	Stick to designated pathways.
Disrupting ecological balance	Avoid removing any organisms from the area. Leave the environment in the same condition as you found it (Figure 5.9.4).
Introducing contaminants (including chemicals and microorganisms) that can disrupt flora and fauna	Ensure you leave no litter behind, including liquid in containers (which can alter the area's scents), when you depart. Refrain from introducing any substances into the water, including beverages.
Disrupting natural animal behaviour	Avoid altering the natural lighting conditions in the area, such as shining a torch at night on possums or owls.

FIGURE 5.9.4 These students are making observations around rockpools using a quadrat, minimising disruption to the surrounding environment by only sampling a small area.

SC 2 CHECK YOUR UNDERSTANDING

Identify one technique used to minimise impact during fieldwork.

KEY TERMS

ethics a set of principles by which your actions can be judged morally acceptable or unacceptable

Country the land that First Nations peoples have a cultural connection to through their ancestry

SC 3 I can analyse ethical and cultural considerations associated with conducting fieldwork

All fieldwork should be planned and conducted in a way that is ethical, responsible and safe. **Ethics** are the moral values that regulate a person's behaviour and the way they conduct activities. In biological fieldwork, for example, ethical behaviour involves maintaining respect for the environment and making sure that no harm is done, which means leaving everything as it was found so as not to disrupt living organisms (Figure 5.9.5).

FIGURE 5.9.5 This scientist is taking photographs of the environment to study later. By only taking a photograph, the scientist is taking care to leave the environment as he found it.

It is also important to consult with the First Nations people whose traditional **Country** will be affected by the work. This can be done through a Native Title group, a Local Aboriginal Land Council or similar body, which helps to ensure that the scientists are not disturbing culturally sensitive locations, such as burial sites (Figure 5.9.6). Finally, it is vital to understand that any ecological knowledge shared by First Nations people remains the rightful ownership of the community, which includes safeguarding their knowledge.

FIGURE 5.9.6 It is important to know the locations of sites of cultural importance for First Nations peoples; this area is in the Pilbara, Western Australia.

Another important thing to remember is that including knowledge from First Nations peoples in fieldwork research is important to make sure all parts of ecosystems are understood. First Nations peoples often have important knowledge about changes to vegetation and seasonal weather variations, for example, which gives scientists unique information about ecological processes over long periods of time. First Nations communities can also identify locations of cultural importance within a research site, making sure scientists conducting fieldwork are being respectful of these sites.

SC 3 CHECK YOUR UNDERSTANDING

Explain why it is important to consider cultural perspectives in fieldwork.

Lesson review

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

1 Define the term 'ecological'.

2 Name three things that a scientist might record about an environment when conducting fieldwork.

3 You are planning fieldwork to observe a population of frogs in a wetland.
   a Identify one technique you could use to minimise your impact on the environment.
   b Explain why minimising impact is important for your study.

4 Explain why scientists might make sketches and take photographs along with their notes and measurements.

5 Describe one way you could address ethical considerations when planning fieldwork in a protected area.

5.10 Using the Linnaean classification system and a dichotomous key in fieldwork

Learning intention

To be able to classify and/or identify organisms in the local environment

Success criteria

SC 1: I can select and plan for methods to observe organisms in the environment.

SC 2: I can use a dichotomous key based on organisms observed in the field.

SC 3: I can use data from observations in the field to determine kingdom, division and class using the Linnaean classification system.

FIGURE 5.10.1 You can use a dichotomous key to identify plants in your local environment.

SAFETY NOTES

- Wear a hat and sunscreen when outside.
- Do not touch any plants.
- Some plants may be poisonous or may cause allergic reactions.
- Do not go into inaccessible areas.

Introduction

You have learnt how to carry out fieldwork effectively and without causing any damage to the environment to be studied. You have also learnt that organisms are grouped according to their similarities and differences to make it easier to classify and identify them. The tool that biologists use is the dichotomous key that is created using specific criteria.

In this practical investigation, you will bring your knowledge together to study a local habitat and classify living things by observation and classifying them using a dichotomous key (Figure 5.10.1).

Background

There are many varieties of plants even in small, local environments. Plants are classified into four divisions: mosses and liverworts, ferns, conifers and seed-producing plants.

Observation of the structural features of plants in the field can be achieved by many different methods. The data collected can be used to organise them into groups according to similarities and differences. This is the basis of classification, and the use of dichotomous keys can identify the plants.

Aim

To use a provided key to identify and classify some plants observed in a local habitat

Materials

- notebooks and pencils
- magnifying glasses or hand lens
- camera
- access to reference books or the internet to research plant classification
- access to the dichotomous key for this activity

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 take you to a local habitat.

1 Observe at least five specimens of plants.
   - Note the distinctive characteristics and structural features. Do this in your notebook for each specimen using dot points.

- Sketch the plant, especially the leaf structure, any flowers if present, cones and fruits, and estimate the size of the plant and the leaves. Try to sketch the leaves or flowers to scale.
- You may need to use a magnifying glass to see any detail.
- Take some photos of the specimens.

GO TO
Toolkit section 5.2, Scientific diagrams

2 Use the dichotomous key (Figure 5.10.2) to classify the plant into the divisions of plants. If the plant is seed-producing, you could try to classify it into its class.

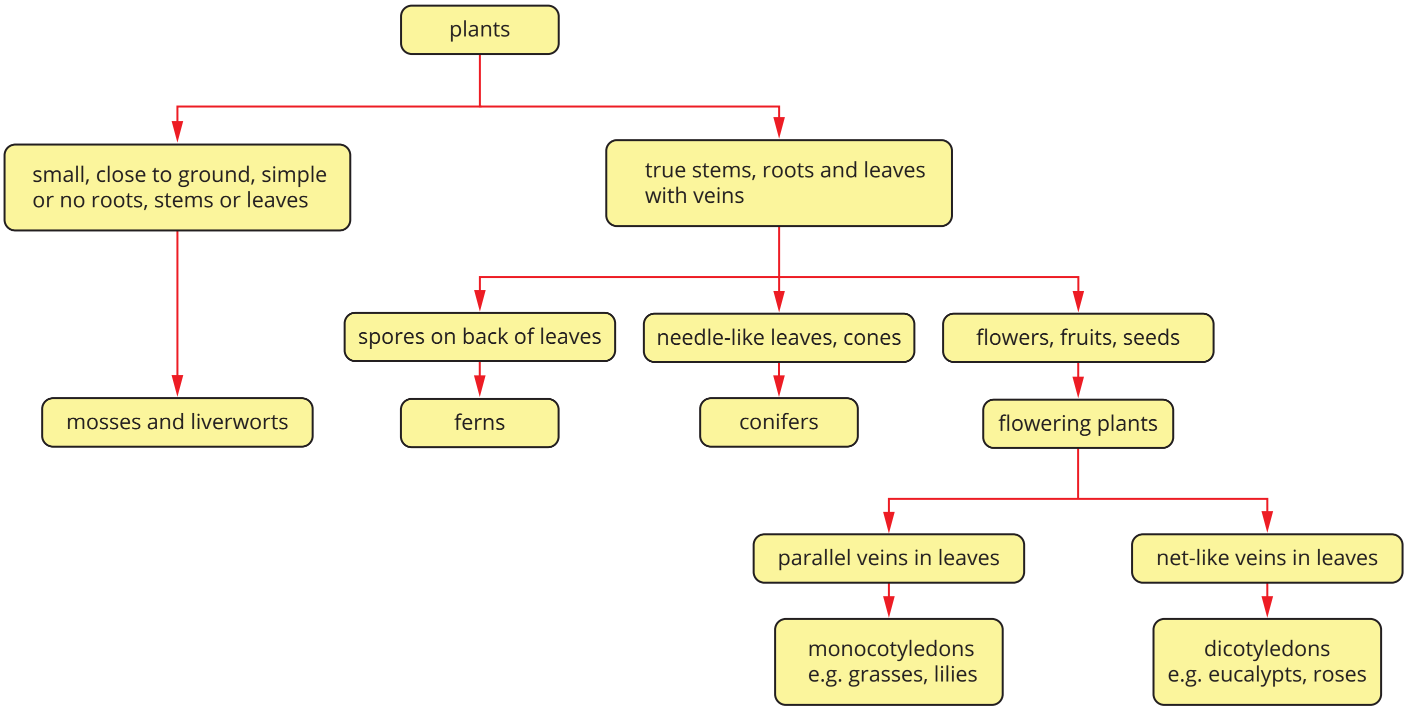


FIGURE 5.10.2 Use this key to help you classify plants in your local habitat.

3 If you have reference material that is more detailed, you could use that to find out the scientific name of the plant.

Results

Present your observations, classification and identification of the plants studied in an organised way. Use the dichotomous key and any other resources available to identify your plant specimens.

Evaluation

1 Swap results with other students to try to classify plants using their observations.

2 Discuss any improvements that you could make to your observations to enable more effective classification.

3 Describe how you reduced your impact on the habitat during your fieldwork.

5.11 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.

SC 3: I can describe how First Nations Australians' knowledge has contributed to development of knowledge of biodiversity.

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, First Nations Australians have unique classification systems that draw on ecological knowledge alongside a deep spiritual and cultural understanding of their environment (Figure 5.11.1).

FIGURE 5.11.1 These grass trees are *Xanthorrhoea australis*, in the Linnaean system, but are called balga, bukkup, baggup or kawee by First Nations peoples (depending on the language groups).

In this lesson, you will learn about the similarities and differences between First Nations Australians' systems of classification and Linnaean classification.

KEY TERM

totem in First Nations Australians culture, a specific animal, plant or natural feature that a person is spiritually linked to; determines relationships with others and rights

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 their spiritual world. 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 it is in its life cycle, 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 5.11.2).

FIGURE 5.11.2 A painting of a dugong from Guugu Yimithirr country in Far North Queensland.

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.

Eucalyptus trees

Many First Nations groups 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 5.11.3). The leaves of some other species, by contrast, are rich in oils that can be used for making ointments and other medicinal remedies.

FIGURE 5.11.3 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 5.11.4). This knowledge is passed down through generations through storytelling, song, dance and other cultural practices.

FIGURE 5.11.4 First Nations Australians may classify kangaroos according to their seasonal movements and the plants they eat.

SC 1 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 18th century, is based on a hierarchical system of grouping organisms by their 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 from the Linnaean classification system. 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 seen as totems or spiritual guides for specific communities that also appear in **Creation stories**, ritual and ceremony, art and storytelling and healing.

KEY TERMS

spiritual relates to the soul or spirit or religious beliefs

Creation stories stories that explain the origins of the universe, the rules for living and the relationship of people to each other and the environment; also known by many as Dreaming stories

KEY TERM

billabong a pond of still water in an isolated branch of a river that fills during a flood

FIGURE 5.11.5 Green turtles are common in Australia's northern waters and around the Torres Strait islands.

FIGURE 5.11.6 Dugongs have many similarities with turtles but are classified as mammals in the Linnaean system because they give birth to live young.

Habitat

First Nations classification systems are often more fluid than the Linnean system and can change over time. For example, in the Yanyuwa peoples' system of classification that separates coastal and inland regions, 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 5.11.5).

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 5.11.6).

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.

SC 2 CHECK YOUR UNDERSTANDING

Explain one key difference between First Nations Australians' classification systems and the Linnaean system.

SC 3 I can describe how First Nations Australians' knowledge has contributed to the development of knowledge of biodiversity

First Nations Australians have a full and detailed knowledge of the biodiversity of their traditional lands, which has been passed down through generations. This knowledge has contributed to an understanding of the importance of biodiversity, the role different species play in their interactions, and the significance of preserving this delicate balance.

In First Nations culture, all organisms are given equal importance, fostering the preservation of biodiversity. Furthermore, First Nations knowledge has provided valuable insights into sustainable land management practices, such as fire management and the use of traditional burning techniques, as well as in the identification and conservation of threatened species and ecosystems.

On the following pages are some examples of how the knowledge of First Nations Australians has contributed to the understanding of biodiversity and development of effective conservation strategies.

Fire management

First Nations Australians have used fire as a tool for thousands of years to manage the landscape and maintain biodiversity. In northern Australia, researchers have observed kites and falcons, known as 'firehawks', intentionally carrying burning sticks to spread fires. This remarkable behaviour challenges Western understanding of how birds interact with fire and highlights the complex relationship, understood by First Nations Australians, between fire management and biodiversity. Recognising the changes in plant biology caused by constant burning and the development of seed pods that only open with fire, First Nations practices encourage more fertile land and the cultivation of new plants, showcasing their extensive ecological knowledge (Figure 5.11.7).

FIGURE 5.11.7 First Nations land management practices such as cultural burning encourage more fertile land and plant germination.

Threatened species conservation

First Nations knowledge has played a key role in the identification and conservation of threatened species, such as the giant barred frog and the northern quoll (Figure 5.11.8). First Nations rangers use their knowledge to monitor and protect these species, and to assist in reintroduction programs.

FIGURE 5.11.8 The endangered northern quoll (*Dasyurus hallucatus*).

Marine conservation

First Nations knowledge plays a vital role in managing and conserving Australia's marine biodiversity. Communities like the Torres Strait Islanders, for example, use their deep understanding of marine animal migrations to develop sustainable fishing practices. In this way, they have maintained a cultural and spiritual connection with the sea for generations.

Traditional stone **weirs**, built over centuries, showcase the technological expertise of First Nations communities along the coast. Similarly, traditional fish traps are cleverly designed to consider genetic diversity by catching only larger fish and preserving the younger generation.

KEY TERM

weir a low barrier built across a river that can be used to raise the level of water upstream and/or control the flow of the river

Respectful rules like taking only what is needed, avoiding undersized or pregnant fish, and preventing overfishing to allow fish to breed and grow maintain both sustainable populations and the wellbeing of communities (Figure 5.11.9).

FIGURE 5.11.9 First Nations knowledge plays a vital role in conserving marine ecosystems.

Knowledge and use of plants

First Nations people possess a deep understanding of native plants' medicinal properties, shedding new light on the way people look at treating diseases such as cancer, respiratory problems and digestive ailments. For example, the blushwood berry native to northern Queensland has been used for centuries by First Nations people to treat various health issues (Figure 5.11.10).

FIGURE 5.11.10 The blushwood berry has been used for centuries by First Nations people to treat various health issues.

SC 3 CHECK YOUR UNDERSTANDING

Explain how traditional ecological knowledge from First Nations Australians has enhanced scientific understanding of biodiversity.

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 List the ways that First Nations Australians manage fish populations to maintain biodiversity.

3 Describe how an organism's habitat may alter its classification using a First Nations Australians classification system.

4 Explain how First Nations fire management can be used to improve ecosystems.

5.12 Changing classification systems

Introduction

Classification systems can change as scientists discover new information or interpret evidence in new ways. As scientists interpret evidence in new ways, their understanding of the relationships between different organisms may change, leading to changes in the classification system.

In this inquiry, you will explore how classification systems change as scientists discover new information or interpret evidence in new ways and you will research an example of this.

Background

Classification systems have changed over time as scientists have discovered new information and developed new methods for analysing data or information. In the past, classification systems were mainly based on morphological evidence, which is the physical characteristics of the organism. This led to classification systems that were based on observable features.

Scientists have used new tools to look at the **DNA** (Figure 5.12.1) of living things and see how they are related to each other. Scientists have learnt more about how different species changed over time. This has led to changes in classification systems, as genetic data has shown previously unknown relationships between organisms and provided information about how they have changed over time.

FIGURE 5.12.1 Scientists can now use methods such as genetic analysis to classify living things.

Aim

To explore examples of changing classification systems as scientists discover new information or interpret evidence in new ways

Learning intention

To explore how classification systems change as scientists discover new information or interpret evidence in new ways

Success criteria

SC 1: I can describe types and/or sources of evidence that affect systems of classification.

SC 2: I can explain how classification systems have changed as a result of new scientific evidence.

SC 3: I can predict how classification systems may change in the future as a result of new technologies and/or scientific evidence.

KEY TERM

DNA the genetic material in organisms that is passed from generation to generation

Plan

1. Using knowledge from this topic and further research, explore the types and/or sources of evidence that affect classification systems and summarise these.
2. Research and describe two examples of organisms that have been reclassified due to new scientific evidence.

Design

GO TO
Toolkit sections 4.3, Selecting and using secondary data and 5.1, Scientific writing

1. Choose one species, or a group of species, that is now classified differently from the traditional Linnaean system due to advances in scientific evidence. Describe the species and explain why this reclassification was of interest to you.
2. Consider how you might present information about this change to an audience. What information will you include and how will you present this information?

Conduct

You will now have an opportunity to create your presentation about a particular classification system that has been changed because of new scientific evidence. You may like to consider the questions below to help guide your content.

- What living thing did you investigate?
- How was the living thing classified in the past? What classification system was used to classify it that way?
- How is the living thing classified now? What classification system is used to classify it this way?
- What new scientific evidence was used that influenced this change?

Share your predictions about how this classification system might change in the future because of new technologies and/or scientific evidence.

Improve

Suggest how you can improve your investigation by considering what worked well, what needed improvement and how you could modify your presentation to make it more effective at communicating the information.

Evaluate

1. In this activity, you planned and conducted an inquiry into classification systems that have changed due to new evidence. What skills did you use during this activity and how did your knowledge of classification systems improve?
2. Use your knowledge of classification and scientific evidence to predict how classification systems might change in the future because of new technologies and/or scientific evidence.

5 Classification and biodiversity

Topic summary

The key concepts included in this topic are:

- Organisms can be classified according to their similarities and differences.
- Scientists classify organisms so they can be easily identified.
- Scientific classification models are used for accurate identification of organisms.
- Dichotomous keys are tools used to identify and classify organisms.
- Changes to classification models occur over time.
- First Nations Australians have a unique way of classifying plants and animals based on their rich cultural understanding of the land.

Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

Remember

1 Identify the main purpose 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 List the steps that would be used to classify a fern using the Linnaean system of kingdom and division.

9 Describe one way that First Nations Australians' knowledge has contributed to development of knowledge of biodiversity.

Apply

10 Gyaan is undertaking fieldwork to identify plants.
- **a** Suggest what type of data could be collected through observation.
- **b** Describe the process of how Gyaan would use the data to classify a shell that was found.

11 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

12 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*) have many common features. Describe the similarities and differences in the classification of these two types of kangaroos.

13 Compare the characteristics of flowering plants and non-flowering plants.

14 Ethics are an important part of scientific research practices.
- **a** Explain the concept of ethics in fieldwork.
- **b** Outline one ethical consideration that you would be mindful of when conducting fieldwork on endangered species.

Extension: Classifying

14 Australian native animals are an important part of biodiversity in Australia.

- **a** Create a set of instructions for creating 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.

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 an animal with an exoskeleton and jointed limbs (e.g. crabs, insects)

biodiversity the number and range of species that exist in an ecosystem, biome or biosphere

billabong a pond of still water in an isolated branch of a river that fills during a flood

celestial relating to the sky or to space

characteristic a feature of a living or non-living thing

Chordata the phylum that includes animals with backbones

chordate an animal with a nerve cord running down its back, and an endoskeleton

class the third level of classification of living things, below phylum and above order

classification the process of putting things into groups

classification key a tool that helps scientists classify organisms based on their observations and descriptions

cnidarian an animal with radial symmetry, one body opening and stinging cells

common name a non-scientific name given to an organism

conifer a plant that bears seeds on cones and has male and female cones on the same tree

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 relationship of people to each other and the environment; also known by many as Dreaming stories

culture a combination of the values, beliefs, language systems, communication and practices that people share

cultural perspective the way that an individual is affected by their environment, as well as social and cultural factors, including race and gender

dichotomous key a key with two choices at each stage

dichotomous question a question that limits responses to only two possible answers

diversity the variety of differences

division the level below kingdom in the classification of plants

DNA the genetic material in organisms that is passed from generation to generation

ecological a description of something that relates to ecosystems or interactions between living things and their environment

ecosystem a system formed by organisms interacting with each other and their non-living surroundings

endoskeleton a skeleton inside the body

ethics a set of principles by which your actions can be judged morally acceptable or unacceptable

exoskeleton a skeleton on the outside of the body

family the fifth level of classification of living things, below order and above genus

fieldwork a practical investigation performed mainly outside in nature

genus the second last level of classification of living things, below family and above species

hierarchy an arrangement that shows items at different levels

hydroskeleton a fluid-filled soft tissue inside the body

Linnaean classification a hierarchical system of classifying organisms, aimed at reflecting their evolutionary relationships

kingdom the first level of classification of living things

marsupial a subclass of mammal that gives birth to immature young that are suckled in a pouch (e.g. koala, kangaroo and wombat)

monotreme a subclass of mammal that lays eggs (e.g. echidna and platypus)

order the fourth level of classification of living things, below class and above family

organism a living thing

phylum the second level of classification of living things, below kingdom and above class

photosynthesis the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from sunlight

pollination the transfer of pollen from anther to stigma

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

spiritual importance a sense of connection to a greater force, like nature, the universe or a higher power

state one of the three forms that matter can exist in—solid, liquid or gas

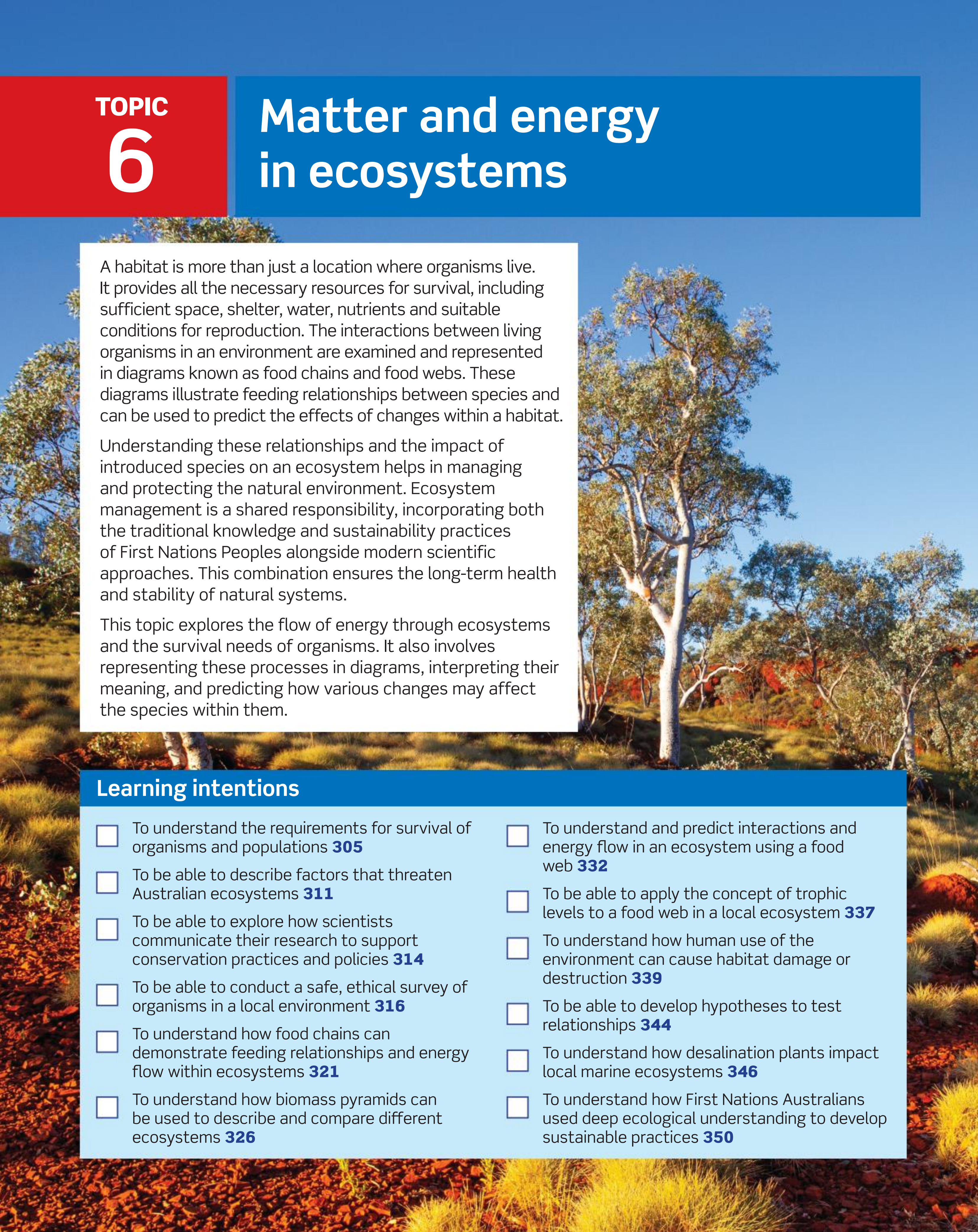
totem in First Nations Australians culture, a specific animal, plant or natural feature that a person is spiritually linked to; determines relationships with others and rights

taxonomist a scientist who specialises in classifying and naming things

taxonomy the science of classifying and naming things

weir a low barrier built across a river that can be used to raise the level of water upstream and/or control the flow of the river

world view a way of considering the world in terms of attitudes, values and beliefs



TOPIC 6

Matter and energy in ecosystems

A habitat is more than just a location where organisms live. It provides all the necessary resources for survival, including sufficient space, shelter, water, nutrients and suitable conditions for reproduction. The interactions between living organisms in an environment are examined and represented in diagrams known as food chains and food webs. These diagrams illustrate feeding relationships between species and can be used to predict the effects of changes within a habitat.

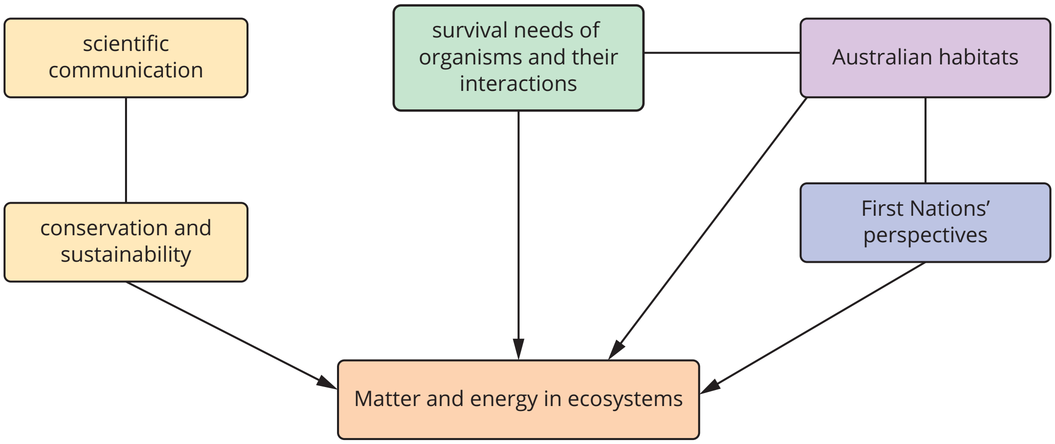
Understanding these relationships and the impact of introduced species on an ecosystem helps in managing and protecting the natural environment. Ecosystem management is a shared responsibility, incorporating both the traditional knowledge and sustainability practices of First Nations Peoples alongside modern scientific approaches. This combination ensures the long-term health and stability of natural systems.

This topic explores the flow of energy through ecosystems and the survival needs of organisms. It also involves representing these processes in diagrams, interpreting their meaning, and predicting how various changes may affect the species within them.

Learning intentions

6 Matter and energy in 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 of organisms and their interactions

1 What are the basic requirements that mammals need to survive?

A food and water

B shelter and suitable conditions

C mating partners

D all the above

2 Explain the factors that make an environment biodiverse.

3 Describe the flow of energy in a food chain.

4 Draw a food chain that demonstrates the following description:

A rabbit eats grass. The rabbit is then eaten by a snake and the snake is preyed upon by a kookaburra.

Australian habitats and First Nations' perspectives

5 List three Australian habitats.

6 Outline two ways humans can have an impact on Australian native plants and animals.

7 Describe how First Nations peoples use traditional knowledge to protect the environment.

6.1 Survival needs

Lesson overview

There is a huge variety of life on Earth. This life comes in different shapes and sizes, with different needs and requirements. All living things must have their needs met for their survival, and life can only exist when these needs are met. Imagine an environment with lots of life and an environment where there is very little life. What is present in both areas that could support life?

In this lesson, you will learn about the six basic needs that all living things require, where these needs can be met and how these requirements allow each organism to survive in their environment.

SC 1 I can describe the basic survival needs of plants and animals in Australia

Learning intention

To understand the requirements for survival of organisms and populations

Success criteria

SC 1: I can describe the basic survival needs of plants and animals in Australia.

SC 2: I can describe a range of habitats in the Australian environment.

SC 3: I can explain the requirements for the maintenance of populations within an ecosystem.

Basic survival needs

In biology the term **biotic factor** is used to describe living things in the **environment**. Earth contains a wide variety of **organisms**, and each organism has different requirements for survival; however, all organisms require the same six basic things:

- nutrition (food sources)
- a water source, to aid vital functions
- a place to live and shelter
- the ability to reproduce
- gases, including oxygen, carbon dioxide and nitrogen
- suitable living conditions, such as a suitable temperature and salinity.

Organisms will only live in places where these needs are met by the **resources** available in the environment.

KEY TERMS

biotic factor a living factor in the environment
environment all the factors in an organism's surroundings that affect its survival
organism a living thing
resource something that meets a particular need or fulfils a particular purpose
adaptation a structure, behaviour or internal bodily function of an organism that helps them survive

Adaptations

Adaptations are features of an organism that allow it to survive in its environment. Plants and animals must adapt to compete for resources and live successfully in their environment.

Adaptations can help organisms survive better in their environment because they are able to hide, control their body temperature and not get eaten.

A good example of a well-adapted animal is the polar bear (Figure 6.1.1). It has white fur to help it hide in the snow, greasy fur to help it dry quickly after a swim and layers of fat to help it stay warm in its cold arctic environment.

FIGURE 6.1.1 A polar bear mother with her cub (*Ursus maritimus*), on Olgastretet pack ice, Spitsbergen, Svalbard Archipelago, Norway

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, phosphorus and potassium to grow strong and healthy.

Biotic and abiotic factors

Ecosystems are made up of two parts: biotic factors and **abiotic factors**.

- Biotic factors are the living parts of an environment, including prey (an animal that is eaten by another animal), predators (an animal that eats another animal), mating partners and competition with another organism for these resources.
- Abiotic factors are the non-living parts of an environment, including water, light, wind, salinity and temperature.

The number of organisms living in a particular space is determined by these factors. A rainforest provides lots of food (Figure 6.1.2), water and mating partners, which allows many organisms to live in that space.

However, in the desert, these factors are limited; therefore, fewer organisms live there.

KEY TERMS

abiotic factor a non-living factor in the environment

habitat the place where an organism lives

FIGURE 6.1.2 Australia has diverse environments—some are rich in wildlife, such as the rainforest, whereas others have fewer organisms, such as deserts.

SC 1 CHECK YOUR UNDERSTANDING

Identify the six basic requirements that organisms require for survival.

Scifile

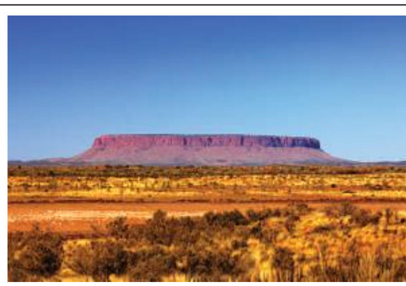
Water is essential

On average, water makes up about 60% of the human body. Without it, humans can only survive for about three days. Water is crucial for all living organisms as it helps with digestion, temperature regulation and transporting nutrients.

SC 2 I can describe a range of habitats in the Australian environment

A place where an organism lives is called a **habitat**. The habitat provides all the environmental requirements an organism needs for survival. Because of its size and varying climate, the Australian environment has a range of habitats. These habitats include wetlands, deserts, coastal waterways and bushland. Read about each of the Australian habitat types in the information in Table 6.1.1.

TABLE 6.1.1 Australian habitat types

Habitat type	Habitat image	Habitat description
Forest	 Australian rainforest, Lamington National Park, Queensland	A forest habitat is dominated by trees and woody vegetation. There is often a thick canopy of leaves at the top of the trees. There are three main types of forest habitat in Australia: dry sclerophyll forest, wet sclerophyll forest and rainforest.
Woodland	 Tropical woodlands, Alkoomie Station, Queensland	A woodland habitat is characterised by trees that are spaced apart with grassland in between. Habitats in woodlands include rocky outcrops, decaying trees and grasslands.
Freshwater	 Lake Dobson, Mount Field National Park, Tasmania	Freshwater habitats have a lot of plant life and water with little dissolved salt. These habitats include ponds, rivers, lakes and billabongs.
Coastal	 A tidal saltmarsh in South Australia	Coasts are places where land meets the sea. This includes a diverse range of habitats such as beaches, rockpools, estuaries, mangroves, salt marshes and coral reefs.
Arid	 Attila (Mount Conner), Central Australian Desert, Northern Territory	Australia is the driest inhabited continent on Earth, with large areas of central desert. Despite the lack of water in deserts, they include several habitats that support life, such as gorges, grasslands and open plain sandy areas.

SCIENCE IN SOCIETY

Coral reefs

Coral reefs are one of the most biodiverse ecosystems on the planet. Coral reefs need clean warm water, plenty of sunlight, and a stable environment in order to be healthy. They are home to thousands of species of fish and other marine organisms, all of which have specific requirements for survival.

In Australia, the Great Barrier Reef is one of the most well-known coral reefs. It not only supports a diverse range of marine life (Figure 6.1.3) but it also contributes significantly to the Australian economy through tourism and fishing. Understanding the needs of the organisms that live in coral reefs helps scientists develop conservation strategies to protect these vital ecosystems.

FIGURE 6.1.3 Feather star (*Oxycomanthus*) on coral in the Great Barrier Reef

Habitat and environment

All ecosystems include a wide range of habitats (where an organism lives). These also include a variety of environments that contain all the interactions between living (biotic) and non-living (abiotic) parts of the ecosystem.

For example, rainforest environments have various factors that affect the organisms that live within it. The canopy of the rainforest contains both living and non-living factors that are different from those on the forest floor (Figure 6.1.4).

FIGURE 6.1.4 The rainforest view from the canopy (top of the forest) and from the forest floor (bottom of the forest)

SC 2 CHECK YOUR UNDERSTANDING

Explain why plants and animals need water to survive.

SC 3 I can explain the requirements for the maintenance of populations within an ecosystem

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. These interactions (Figure 6.1.5) determine how many organisms can live in a particular space at any time.

Communities contain different **species**, which fill specific roles in the ecosystem. Organisms of the same species that are living together in the same area are called a **population**.

KEY TERMS

ecosystem a system formed by organisms interacting with each other and their non-living surroundings

community groups of organisms that interact within an ecosystem

species different types of living things

population a group of organisms of the same species that live in the same area

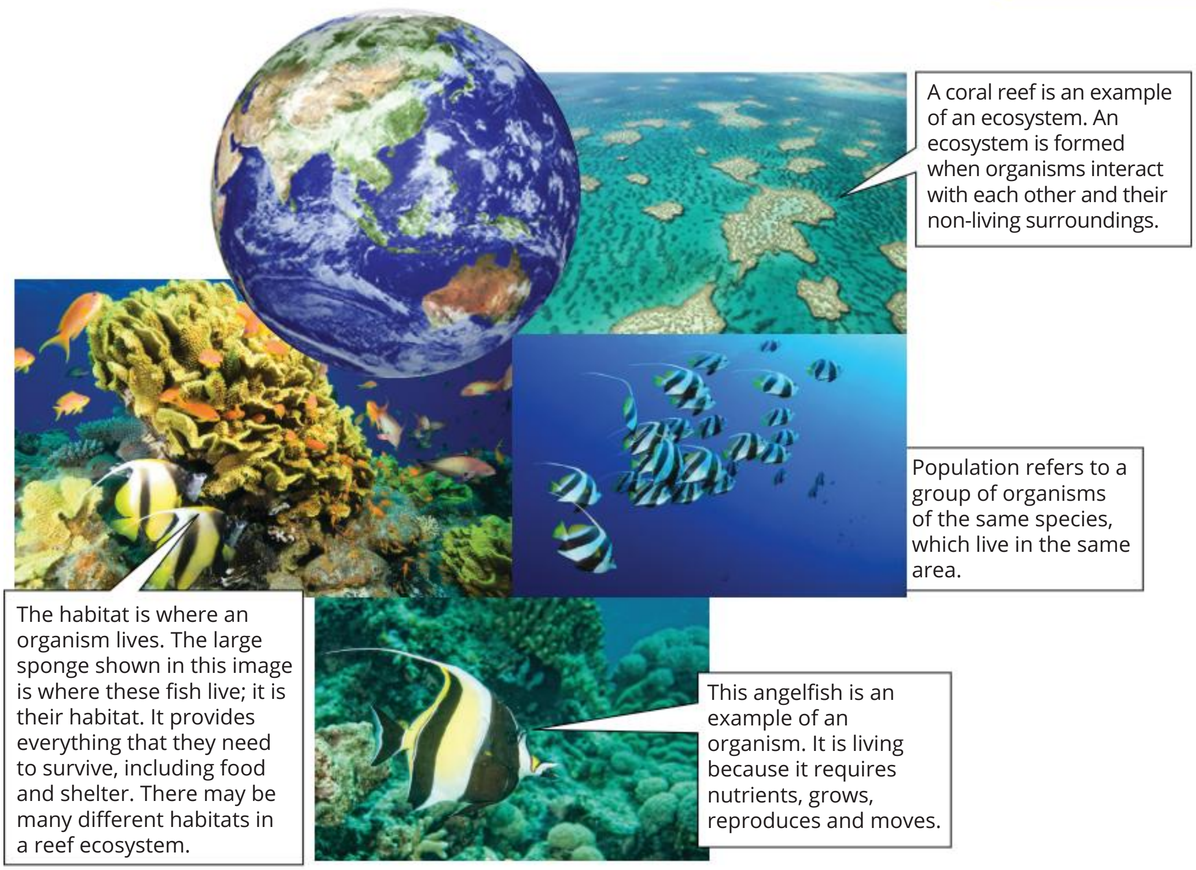


FIGURE 6.1.5 The relationship between ecosystems, habitat and the organisms that live there

Changes in a population are related to the availability of resources in an ecosystem. 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.

KEY TERMS

biodiversity the number and range of species that exist in an ecosystem, biome or biosphere

tolerance the ability of an organism to survive under particular conditions

genetic relating to heritable characteristics or features passed on from parent to offspring

A healthy ecosystem is home to many different species. The more species an ecosystem has, the higher its **biodiversity**. All species differ from one another in their resource use, **tolerance** to changes in the environment (such as temperature or rainfall) and their interactions with other species.

The importance of biodiversity

Ecosystems thrive when there is variation. Biodiversity has three important and intertwined parts:

- species diversity
- ecosystem diversity
- **genetic** diversity.

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.

FIGURE 6.1.6 Managed ecosystems might include cleared land for crops or grazing as well as built features such as roads, fences or wind turbines.

Ecosystem management

Ecosystems are either wild or managed.

Wild ecosystems have little to no human influence, such as savannas or deserts. These natural ecosystems preserve biodiversity. For example, maintaining predator–prey relationships in an ecosystem helps manage population numbers so that prey species do not become too numerous. This balances the ecosystem because other species can also use available resources, and biodiversity continues.

Managed ecosystems are areas that have been heavily affected by humans, such as farms (Figure 6.1.6). These usually reduce biodiversity to a limited number of species.

SC 3 CHECK YOUR UNDERSTANDING

List three factors that can affect population numbers in an ecosystem.

Lesson review

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

1. Define the term 'biotic factor'.
2. List three abiotic factors that can be found in an arid environment.
3. How do rainforest habitats differ from those of a desert habitat in Australia?
4. Explain how the survival needs of a kangaroo would be different from those of a eucalyptus tree in Australia.
5. Explain why it is important to maintain balanced predator–prey relationships in an ecosystem.
6. Seawater temperature is one of the most important factors affecting the population size and diversity of life in seas. Explain how one abiotic factor, such as seawater temperature, could alter the biodiversity of the Great Barrier Reef.

Inquiry activity

6.2 The Australian environment today

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. In this inquiry activity, you will investigate why there are so many endangered species in Australia and the causes of population decline threatening Australian species.

Background

Ecosystems that are diverse and can provide for the needs of the organisms that live there are **sustainable** ecosystems. However, many factors can affect the long-term health of an ecosystem. These factors include habitat loss (Figure 6.2.1) and natural disasters such as fire (Figure 6.2.2), 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 change in an ecosystem this may lead to a loss of biodiversity.

Australia is a known biodiversity hotspot, so why are there so many **endangered species** in Australia, and what is the cause of their population decline?

In this inquiry activity, you will look at some of the reasons a population is in decline and consider the dangers if the population continues to decline.

Learning intention

To be able to describe factors that threaten Australian ecosystems

Success criteria

SC 1: I can describe specific threats to Australian ecosystems.

SC 2: I can explain the dangers of loss of biodiversity in Australia.

SC 3: I can describe how abiotic and biotic factors are affecting a local ecosystem.

KEY TERMS

sustainable using resources in a way that keeps Earth healthy for a long time

endangered species an animal or a plant that is at serious risk of disappearing forever

FIGURE 6.2.1 Raptors such as this hawk are at risk of population decline because of habitat alteration or destruction.

FIGURE 6.2.2 Bushfires are a natural process in the Australian environment. However, uncontrolled wildfires can have devasting effects on ecosystems.

Endangered Australian species

The Australian organisms in Table 6.2.1 are all endangered species.

TABLE 6.2.1 Endangered Australian species

Lord Howe Island stick insect	Leadbeater's possum	Helmeted honeyeater
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.	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.

Aim

To create a pamphlet or poster through print or digital media that will educate your community about an Australian endangered species

Plan

GO TO Toolkit sections 4.3, Selecting and using secondary data and 5.1, Scientific writing

1. Select an Australian plant or animal species that is endangered.
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 its breeding season, and how often does it breed?
   - How many young does it have in each breeding season?
   - What is its diet?
   - What threats are in the ecosystem leading to this species being endangered?
   - What **conservation** strategies are already in place?
   - What are the risks to the ecosystem if the population of the species continues to decline?

KEY TERM

conservation the protection of resources, such as land and biodiversity

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, pencils), or create your poster digitally.

Improve

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.

Evaluate

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.

6.3 Scientific communication

Learning intention

To be able to explore how scientists communicate their research to support conservation practices and policies

Success criteria

SC 1: I can explain the importance of communicating scientific research.

SC 2: I can describe how Dame Jane Goodall influenced conservation policies.

SC 3: I can describe how Dame Jane Goodall's communication of her research changed individual viewpoints.

FIGURE 6.3.1 Dame Jane Goodall is communicating her life-long research on primates

Introduction

Scientists communicate their research through a variety of methods to support their findings. For example, they may publish papers in peer-reviewed scientific journals, present their findings at conferences and workshops and communicate with policy-makers and members of the public through popular media and educational outreach programs. Ecologists or scientists working in conservation share their findings with organisations to help them make informed decisions about conservation practices and policies.

In this inquiry activity, you will explore how scientists communicate their research to support conservation practices and policies. In particular, you will explore how Dame Jane Goodall (Figure 6.3.1) communicated her research.

Background

The effective communication of scientific research is important because it:

- allows other scientists to verify and build upon the current work, leading to further advancements in knowledge and understanding
- ensures that policy-makers, decision-makers and the public have access to accurate and up-to-date information, which is essential for informed decision-making and for addressing important issues
- can increase public understanding of scientific issues, which can lead to greater public interest and support efforts in these areas
- can bridge the gap between scientists and the public, fostering trust and collaboration between these groups and ultimately lead to more effective efforts
- can help to avoid misconceptions and misinformation, which can have harmful consequences.

Dame Jane Goodall is a renowned primatologist and conservationist who has had a significant influence on conservation policies through her research and advocacy. Conservation policies are rules and guidelines that are put in place to protect the natural environment, including animals, plants and their habitats. They achieve this by regulating human activities that may harm ecosystems. Conservation policies are designed to promote sustainability and preserve natural resources for future generations. This inquiry activity will develop your understanding of how scientists like Dame Jane Goodall communicate their research and how doing so can support conservation practices and policies.

Aim

To explore how scientists such as Dame Jane Goodall communicate their research to support conservation practices and policies

Plan

1 Explore how scientists communicate their research to support conservation practices and policies.

2 Explore and explain how Dame Jane Goodall communicates finding from her research, providing examples.

3 Investigate how Dame Jane Goodall influenced conservation policies.

GO TO
Toolkit sections 4.3, Selecting and using secondary data, 4.2, Referencing secondary data and 5.1, Scientific writing

Design

1 Choose a conservation topic that is currently in the spotlight in Australia.

2 Using your research into effective scientific communication, consider how you could communicate key scientific learnings. What platform would you use to present this information? What key headings would you use to structure your work?

Conduct

1 Research your topic of interest. Note your key findings.

2 Create a presentation sharing your findings about this topic and its influence on conservation in Australia.

Improve

1 How could you improve your communication strategy for sharing scientific information?

2 Would you change any key headings or the platform you used to communicate? How and why?

3 To what extent do you feel you communicated your conservation topic effectively?

Evaluate

1 What aspects of conservation did you investigate in this inquiry activity?

2 In this activity, you planned and conducted an inquiry into effective communication strategies to support conservation practices and policies. What skills did you use during this activity?

6.4 Organisms and habitats in the school grounds

Learning intention

To be able to conduct a safe, ethical survey of organisms in a local environment

Success criteria

SC 1: I can carry out a sampling technique.

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.

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 6.4.1).

FIGURE 6.4.1 When you explore a habitat and conduct field work, you collect samples and data to learn more about the ecosystem and make predictions.

Background

Living organisms can survive in a range of habitats. There are very few places in the world that have no living organisms.

The organisms living on school grounds will vary depending on the location of the school, but there will be habitats available for this practical.

Aim

To investigate the organisms that are living in various habitats on the school grounds

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

SAFETY NOTES

- Wear protective gloves when handling any organisms, and wash your 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.

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. 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. Sketch 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.

GO TO
Toolkit sections 2.2, Ethical behaviour and safety in science and 3.3, Designing a results table

SkillBuilder

Recording results using sampling

Using sampling to gather data

When studying ecosystems, it is impossible to observe the whole ecosystem. Instead, **sampling techniques** are used to measure aspects of the ecosystem (such as the organisms in the ecosystem).

When using sampling, 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 a 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 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. Smartphones 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 earthworms were in the bushland on his school grounds. Amin used a 1 m × 1 m (1 m^2) quadrat to survey an area of bushland and he found four earthworms. The total area of bushland was 40 m^2, so he estimated a total population of 160 earthworms in the bushland (4 earthworms per metre × 40 metres).

SkillBuilder

Ethical collection of data

Ethics are moral principles that govern a person's behaviour. In science, ethics ensure that scientific research is conducted safely and fairly and that the rights of people, animals and the environment are protected.

Ethics in science

Ethical behaviour in science includes:

- being honest with data
- avoiding bias when interpreting results
- sharing data and methods with other scientists
- crediting sources of information correctly
- protecting the rights of humans
- protecting animals and the environment.

The rights of humans

Protecting the rights of humans includes:

- making sure that nobody is physically, mentally or emotionally harmed in science experiments
- recognising First Nations Australians, heritage sites and avoiding disturbing these sites
- obtaining informed consent from all participants in research that involves people.

Protecting the living environment

Protecting the living environment includes:

- planning experiments to minimise disturbance and eliminate any potential for harm to animals
- ensuring all animals that have been trapped are released safely back into their original habitat
- using observation techniques that minimise any damage to the environment
- replacing the use of animals with other techniques where possible, such as simulations.

Example

Marcella was conducting an environmental survey in their local bushland. They:

- checked who owned the land to get permission to complete the survey
- conducted the survey with just one other person to avoid too much damage to the ecosystem
- used a quadrat to sample small sections of bushland
- ensured that they had appropriate clothing to protect their arms and legs from Sun exposure, insects and scratches from small branches when walking through the bush
- used their mobile phone to take photos rather than remove samples
- shared the results of the survey with the owner of the land.

GO TO
Toolkit section 3.3, Designing a results table

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. Record your results in the table.

2 Predict if the results from the 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.

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.

Evaluation

GO TO
Toolkit section 2.2, Ethical behaviour and safety in science

Evaluate your practical investigation. Include how you considered ethics, including ways to reduce risk and damage to the environment when conducting fieldwork.

6.5 Food chains

Lesson overview

Energy is captured from the Sun 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 6.5.1). 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. In this lesson, you will learn about the relationships organisms have with each other and how energy flows through ecosystems.

SC 1 I can construct a food chain based on an Australian ecosystem

All organisms need energy to survive. Plants are called **producers** because they make their energy by using 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 6.5.2).

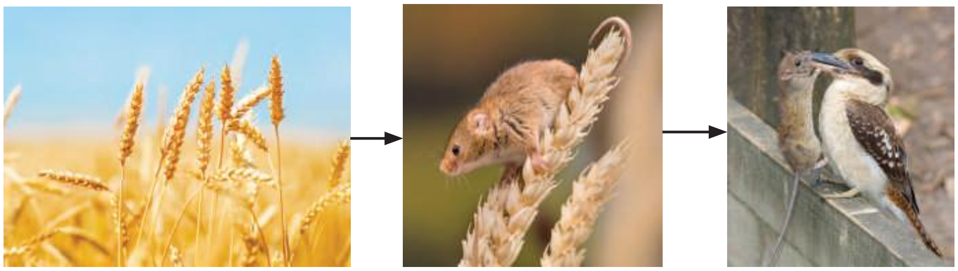


FIGURE 6.5.2 The Sun provides energy for the wheat, which provides energy for the harvest mouse, which provides energy for the kookaburra.

If the kookaburra dies, then **decomposers** such as bacteria or fungi break down the remains and return the nutrients to the soil.

SC 1 CHECK YOUR UNDERSTANDING

What is the correct definition of a producer?

A Needs to eat other organisms to survive
B Needs to break down other organisms to survive
C Needs to produce sunlight to gain their energy
D Needs to capture sunlight to manufacture its own energy

Learning intention

To understand how food chains can demonstrate feeding relationships and energy flow within ecosystems

Success criteria

SC 1: I can construct a food chain based on an Australian ecosystem.

SC 2: I can identify producers and primary, secondary and tertiary consumers in a food chain.

SC 3: I can describe specific feeding relationships, including predator–prey, in Australian terrestrial and aquatic ecosystems.

FIGURE 6.5.1 A koala snacks on eucalyptus leaves.

KEY TERMS

producer an organism able to manufacture its own food; plants are producers
consumer an organism that must eat other organisms to get the energy and nutrients it needs
food chain the flow of energy from organism to organism in a series of feeding relationships
decomposer an organism that gets the energy it needs by breaking down dead matter and waste products

KEY TERMS

primary consumer a consumer that only eats plants, algae and other producers; also known as first-order consumer

secondary consumer a consumer that eats a primary consumer; also known as second-order consumer

tertiary consumer a consumer that eats a secondary consumer; also known as third-order consumer

apex predator a predator that has no natural predators except humans

SC 2 I can identify producers and primary, secondary and tertiary consumers in a food chain

The flow of energy from organism to organism in an ecosystem can be shown in a food chain. The direction in which the arrow is pointing shows the direction of energy flow. The grass is the producer as it obtains its energy from the Sun. Each organism in the food chain increases in consumer level. Figure 6.5.4 is an example of a grassland food chain.

The caterpillar is a **primary consumer** (also known as a first-order consumer) as it consumes the producer.

The frog is the **secondary consumer**.

The owl is the **tertiary consumer**.

Food chains always end with the top predator or **apex predator**, which is not preyed upon by any other organism but will be decomposed after its death. In this food chain, the owl has no natural predators, so it is the apex predator.

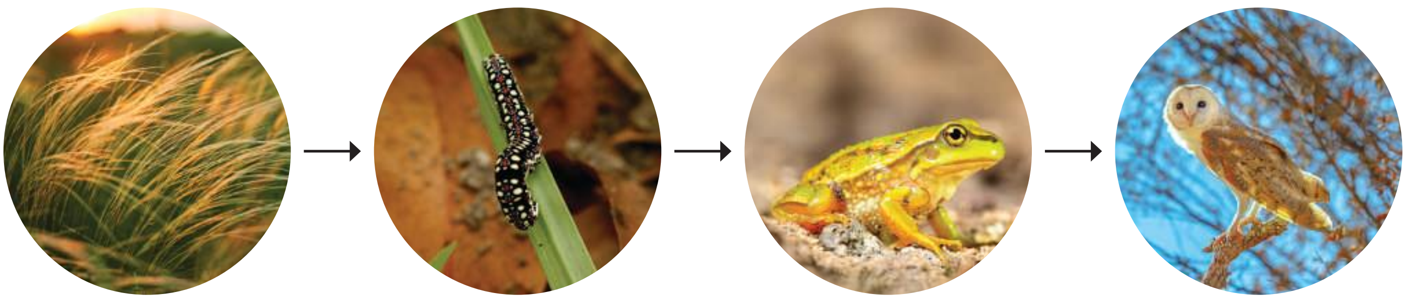


FIGURE 6.5.4 A grassland food chain showing the direction of energy flow

Food chains are not usually bigger than four steps, this is because too much energy is lost between each step and the energy available for the next organism will be lost.

Energy can be lost in a few ways; for example, through heat and in removal of waste such as faeces (digestive waste). Figure 6.5.5 is another example of a grassland food chain.

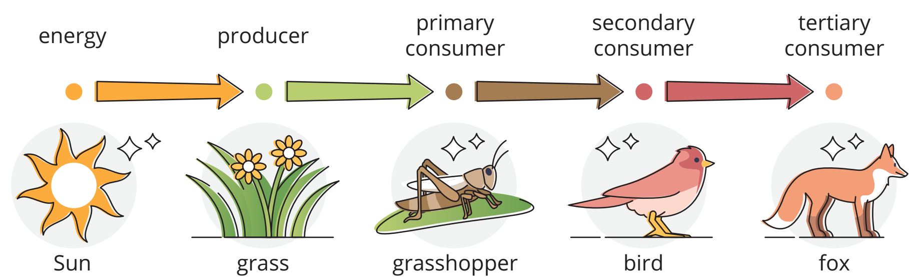
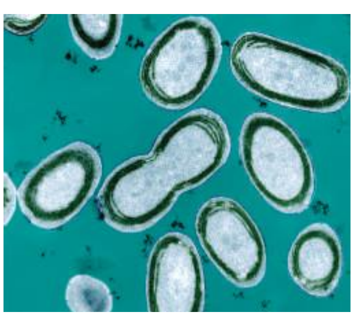


FIGURE 6.5.5 A food chain showing different producers and consumers

Scifile

Primary tiny producers

In a food chain, primary producers like plants and algae create energy through photosynthesis. Scientists estimate that about half of the oxygen production on Earth is produced by oceanic plankton, drifting plants, algae and some bacteria that can photosynthesise.



When you join all of the food chains in an ecosystem, you create a **food web** (Figure 6.5.6). Food webs are a representation of the relationships between lots of organisms.

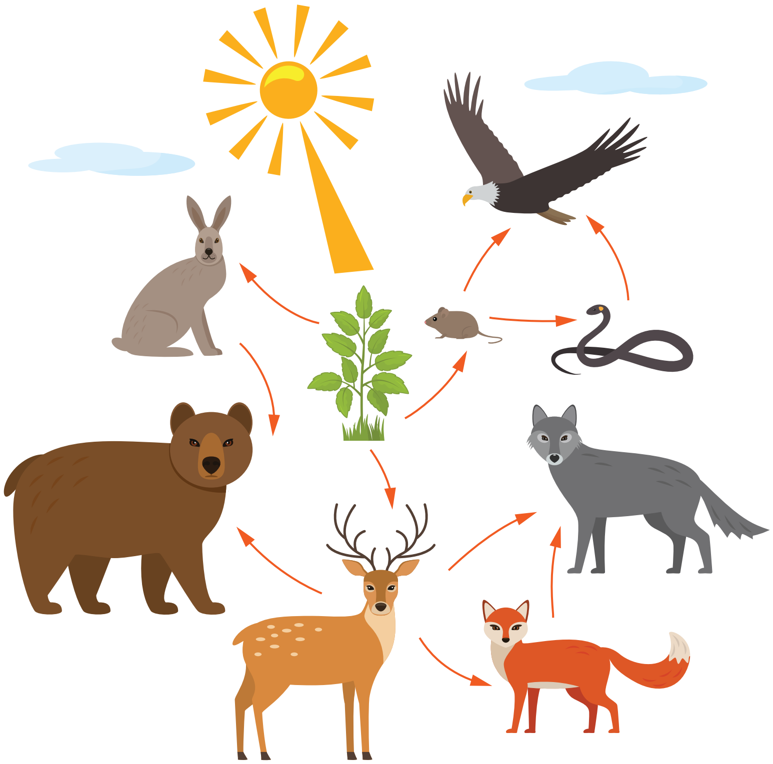


FIGURE 6.5.6 An example of an interconnected food web

KEY TERM

food web a diagram representing two or more connected food chains

Scifile

Apex predators

Apex predators, like sharks, bears, wolves and eagles, are at the top of the food chain. They have no natural predators and play a crucial role in maintaining the balance of ecosystems.

A great white shark (*Carcharodon carcharias*), hunting and eating a seal

SC 2 CHECK YOUR UNDERSTANDING

Look carefully at the photo in Figure 6.5.7 and consider the food chain it represents.

a Which is the producer?
b Which is the primary consumer?
c Which is the secondary consumer?
d Although it is not pictured, what might be an apex predator in this food chain?

FIGURE 6.5.7 The smallest sea creatures, plankton, attract bait balls (tightly packed spherical groups of fish) of sardines, which then attract sea lions.

SC 3 I can describe specific feeding relationships, including predator–prey, in Australian terrestrial and aquatic ecosystems

In an ecosystem, a variety of organisms live together and rely on each other in many ways. Living organisms affect each other when they compete for resources such as food, shelter, mates and a suitable environment. Some of these relationships are helpful and some are harmful.

Competition

Competition can occur between members of the same species or between different species. For example, when a tree in the rainforest drops its seeds, if they fall in the same place, the seedlings will compete for sunlight availability, space, as well as nutrients and water from the soil (Figure 6.5.8).

FIGURE 6.5.8 Seeds competing for the same resources in a rainforest

KEY TERMS

competition a relationship between organisms that are trying to use the same limited resource

predator an animal that kills and eats other animals

prey an animal that is eaten by a predator

FIGURE 6.5.9 A pitcher plant consumes a moth.

FIGURE 6.5.10 Numbats are carnivores.

Predator–prey relationship

Predation is a relationship where one organism kills and eats another. In this feeding relationship, the attacker is the **predator** and the one being eaten is the **prey**. In Figure 6.5.9, a moth is being consumed by a pitcher plant. The predator is the pitcher plant, and the prey is the moth.

Types of consumers

The following terms are used to describe different types of consumers.

Herbivore: A herbivore is an organism that feeds only on plants such as grass, leaves, roots and vegetables. Examples of herbivores are wombats, kangaroos, sugar gliders and caterpillars.

Carnivore: A carnivore is an animal that feeds only on other animals. Examples are quolls, sharks, eagles, numbats (Figure 6.5.10) and the Tasmanian devil.

Omnivore: An omnivore is an organism that feeds on both plants and animals. The Australian bandicoot is an example of an omnivore. It eats roots, insects, worms, berries and fungi. Other examples of omnivores are the emu, bilby and bobtail lizard.

Examples of feeding relationships and their position on the food chain

Table 6.5.1 shows some examples of feeding relationships and the organism's position on the food chain.

TABLE 6.5.1 Feeding relationships and the organism's position on the food chain

Bobtail lizard	Gum moth caterpillars	Rose gum eucalyptus trees
consumer—omnivore	consumer—herbivore	producer
Consume: a variety of plants and insects, including flowers and beetles	Consume: eucalyptus leaves	Consume: use sunlight, water and carbon dioxide to produce their own food
		

SCIENCE IN SOCIETY

Urban food chains

Food chains are not just found in natural ecosystems; they also exist in urban environments (e.g. Figure 6.5.11). In a city, a simple food chain might start with plants growing in a park or garden. These plants are eaten by insects, which are then eaten by birds. The birds might then be preyed upon by larger animals such as cats or hawks.

Understanding urban food chains can help scientists and city planners develop strategies to support urban biodiversity. This might include planting native plants to provide food for insects and birds, or creating green spaces that support a variety of species.

FIGURE 6.5.11 An example of an urban environment is Parramatta Park and river near Sydney, New South Wales.

SC 3 CHECK YOUR UNDERSTANDING

Would a herbivore or a carnivore be closer to the start of a food chain? Explain your answer.

Lesson review

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

1 Explain why producers are essential in a food chain.

2 Explain how 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 Define a predator–prey relationship.

5 An organism eats leaves, roots, insects and sometimes small mammals. Identify its position on the food chain and its feeding relationship. Give reasons for your answer.

6 Describe a predator–prey relationship in an Australian aquatic ecosystem.

7 Describe how you would construct a food chain for a coastal Australian ecosystem.

6.6 Biomass pyramids

Learning intention

To understand how biomass 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 describe the flow of energy through a biomass pyramid.

SC 3: I can measure and compare the flow of energy within biomass pyramids using provided data.

KEY TERMS

biomass all plant and animal matter on Earth
biomass pyramid a visual representation of the biomass at different levels of a food chain
mass the amount of matter in a substance or object; measured in grams (g), kilograms (kg) or tonnes (t)
trophic level the position of an organism in a food chain
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
terrestrial on land

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. But, have you ever wondered how energy moves through these different levels of the ecosystem?

In this lesson, you will learn about the concept of biomass and biomass pyramids, which tell us about the mass of all 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

Biomass is material from living things that can be used to make energy. A **biomass pyramid** can be used to visualise the total **mass** of all the organisms in a food chain at the different feeding levels. These diagrams describe the quantity or mass of the of the organisms at each of the **trophic levels** that you can see in a food chain or food web.

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 stage (Figure 6.6.1).

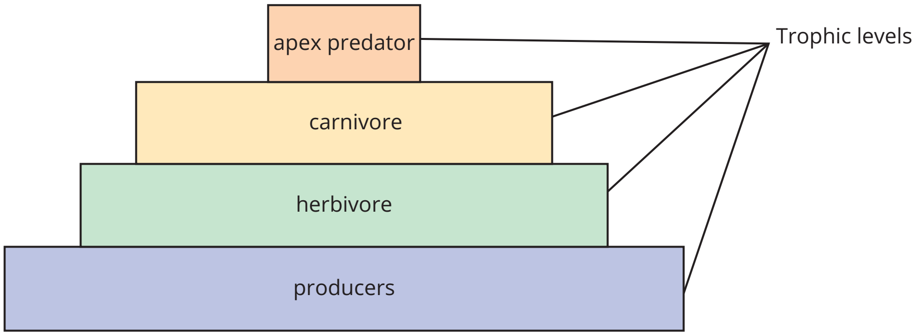


FIGURE 6.6.1 A generalised terrestrial biomass pyramid showing each trophic level from largest (bottom level – producers) to smallest mass (top level – apex predators)

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 above them.

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 6.6.2 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.

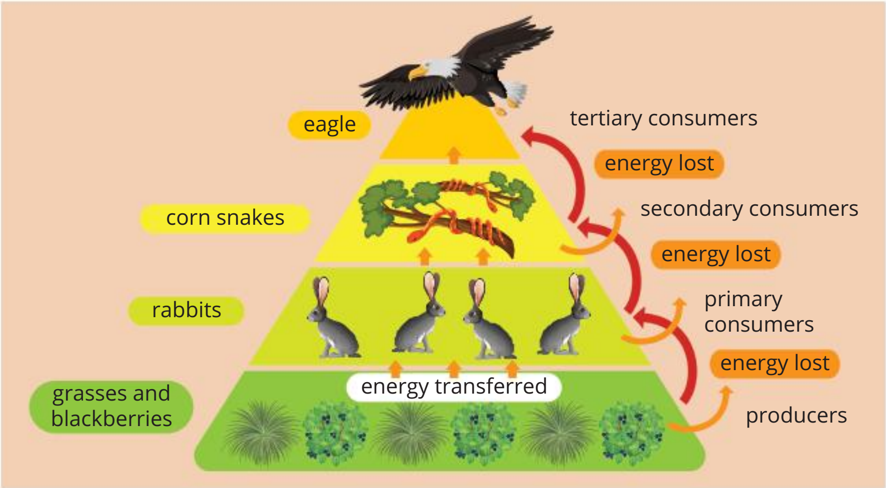


FIGURE 6.6.2 This biomass pyramid shows how energy flows through a terrestrial ecosystem.

SCIENCE IN SOCIETY

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 (Figure 6.6.3).

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.

FIGURE 6.6.3 The green tree python (*Morelia viridis*) is a predator in the Daintree rainforest, Queensland.

Aquatic biomass pyramids

Aquatic biomass pyramids are often drawn upside down. They are also a visual representation of the food chains in water except that the producers are on the top and the apex predators are on the bottom.

The pyramid is inverted because the total mass of aquatic producers, such as plankton and seaweed, can be much smaller than the mass of large organisms that live in the ecosystem, such as whales. Figure 6.6.4 shows a biomass pyramid for a community consisting of seaweed, parrotfish, sharks and killer whales. In this food chain, parrotfish consume the seaweed, transferring energy to the sharks that eat them. The sharks are then hunted and eaten by the killer whale.

KEY TERM

aquatic in water environments such as ponds, lakes, oceans and seas

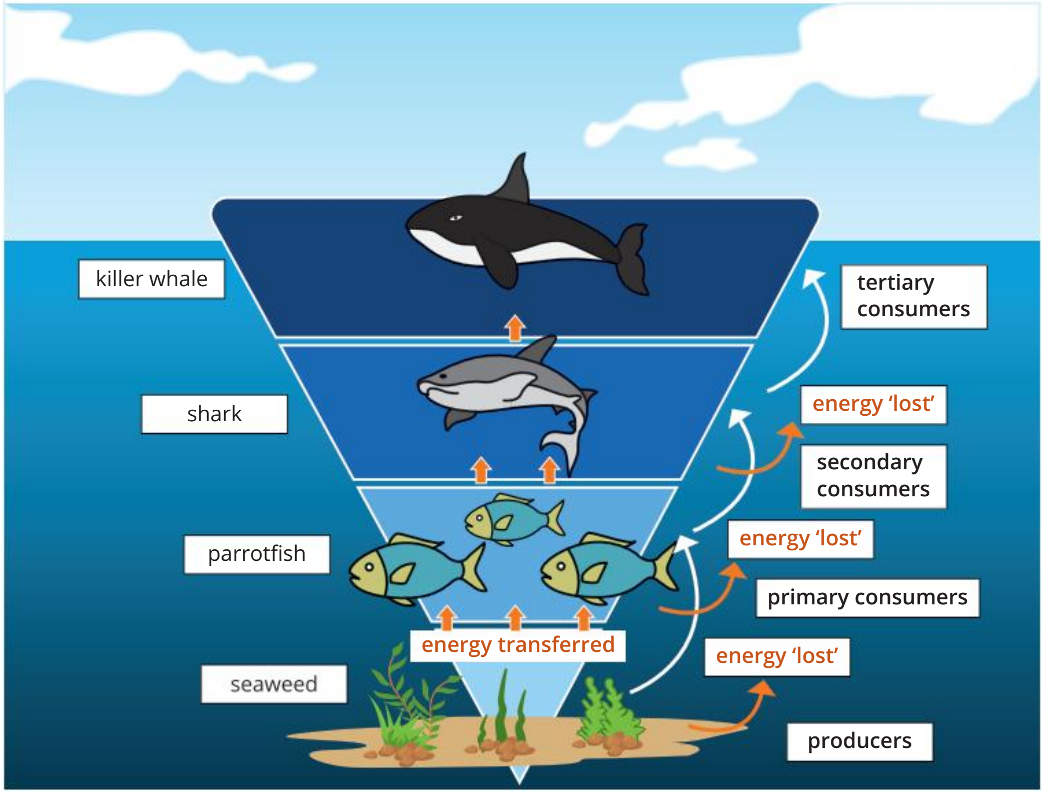


FIGURE 6.6.4 This biomass pyramid shows how energy flows through an aquatic ecosystem.

Pyramids of numbers

KEY TERM

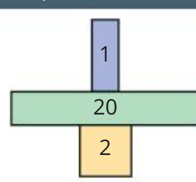
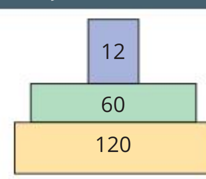
pyramid of numbers a diagram representing the number of organisms in an ecosystem

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 be 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 as shown in Table 6.6.1.

TABLE 6.6.1 Pyramid of numbers vs 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

Outline the difference between a biomass pyramid and a pyramid of numbers.

SC 2 I can describe the flow of energy through a biomass pyramid

All living things need energy to survive. Energy enters an ecosystem as sunlight and is converted by plants into chemical energy through the process of photosynthesis. This energy is then used by plants for growth and other plant functions.

Energy is also used up by animals in everyday functions. An example of this is a chicken losing heat energy while running. This energy is now 'lost' from the food chain, so less energy is available to the next consumer.

Usually only 10% of energy is passed on from one consumer to the next; this means that 90% of energy is used up from the level below. The example in Figure 6.6.5 shows 90% of energy being lost from the chicken (first-order consumer) and only 10% going directly to the farmer (second-order consumer).

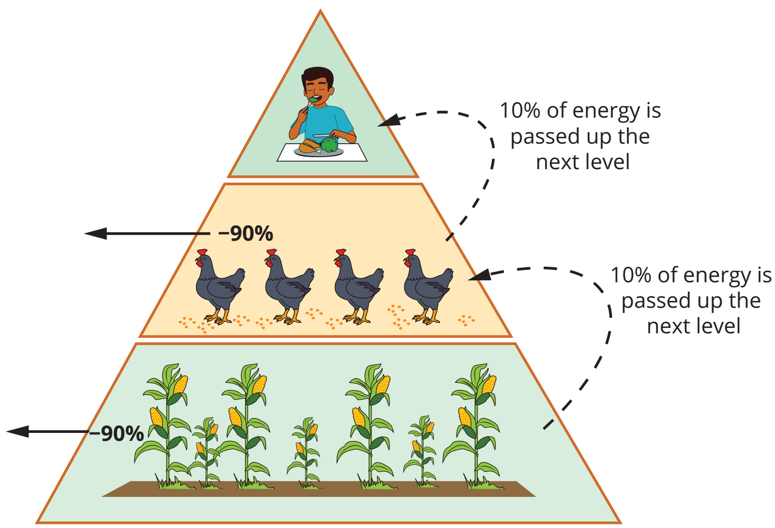


FIGURE 6.6.5 The amount of energy available reduces the further you go up the biomass pyramid.

SC 2 CHECK YOUR UNDERSTANDING

In a biomass pyramid, identify the total amount of energy:

a transferred between levels

b lost between levels.

SC 3 I can measure and compare the flow of energy within biomass pyramids using provided data

Energy transfer in food chains

A healthy ecosystem has 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 only consumes the remaining biomass.

Efficiency of biomass transfer in food chains

The efficiency 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:

$$\text{efficiency of biomass transfer} = \frac{\text{amount of biomass transferred to the next level}}{\text{biomass that was available at the previous level}} \times 100\%$$

Calculating energy flows

Using Figure 6.6.6 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.

$$\frac{\text{10 kg birds}}{\text{100 kg grasshoppers}} \times 100\% = 10\% \text{ transfer}$$

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.

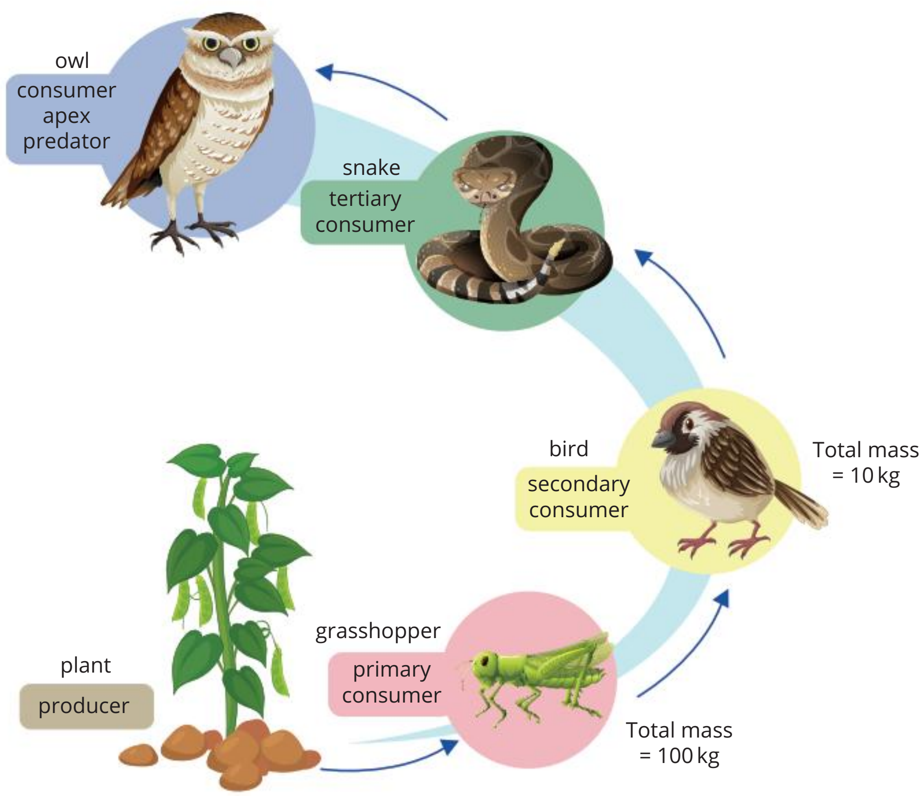
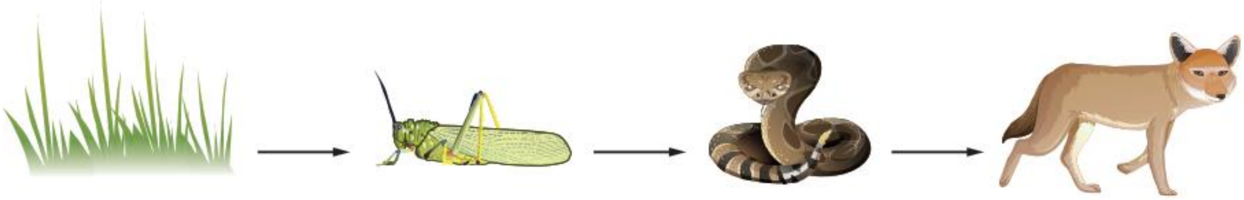


FIGURE 6.6.6 Energy flow among the organisms in a food chain through biomass transfer

Using calculations such as these, the energy flow in different biomass pyramids can be compared.

SC 3 CHECK YOUR UNDERSTANDING

Calculate the efficiency of biomass in this food chain.



grass	grasshopper	snake	fox
total mass 1200 kg	total mass 122 kg	total mass 14 kg	total mass 1.2 kg

Lesson review

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

1 Define a biomass pyramid.

2 Identify the primary source of energy for most biomass pyramids.

3 Compare the 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.

6.7 Food webs

Learning intention

To understand and predict interactions and energy flow in an ecosystem using a food web

Success criteria

SC 1: I can create a food web from information about feeding relationships in an ecosystem.

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 use relationships from a food web, and the concept of competition, to predict the effect of population changes within an ecosystem.

HINT

When constructing a food web, draw all the producers at the same level on the diagram. Make sure that the primary consumers are aligned and the secondary consumers are aligned. This is not always possible, especially with complex food webs, but it makes the food web easier to follow.

GO TO
Toolkit section 5.4, Graphic organisers

Lesson overview

The flow of energy from one organism to another in an ecosystem can be shown in a food chain. However, animals rarely eat just one type of food. Most animals have a varied diet that depends on what they can catch or what is available during different seasons. These relationships can be shown using interconnected food chains, which are called food webs. Much like a spider web, food webs have many points of connection.

In this lesson, you will learn about how food chains interconnect to become food webs to be able to predict changes in populations in an ecosystem.

SC 1 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 6.7.1 contains several food chains, including:

1 carrot → rabbit → fox

2 grass → grasshopper → owl

3 grass → grasshopper → bird → fox

4 grain → mouse → owl

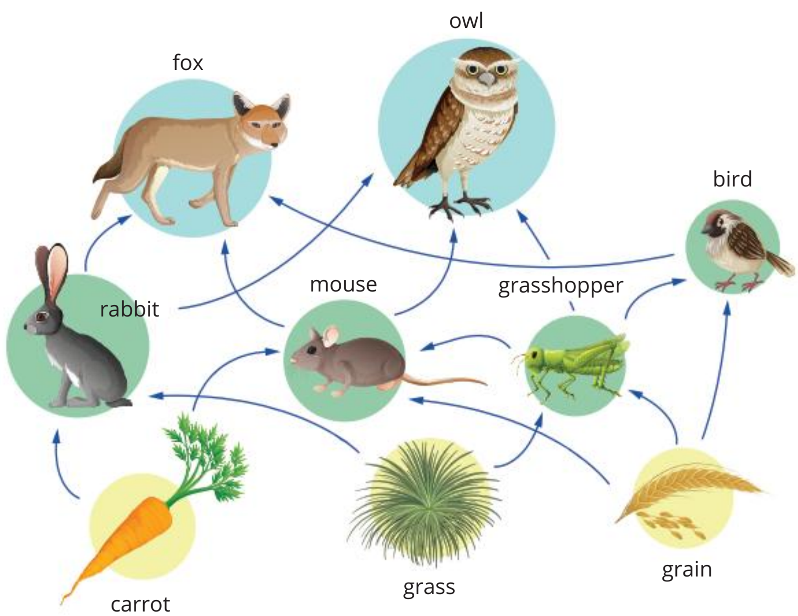


FIGURE 6.7.1 Food webs show the many places that energy can flow.

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.

SC 1 CHECK YOUR UNDERSTANDING

Use Figure 6.7.1 to identify one example of each of the following trophic levels.

a producer
b primary consumer
c secondary consumer
d tertiary consumer

SC 2 I can explain the energy pathways in a food web, including identifying producers, different levels of consumers and apex predators

Purpose of food webs

Food webs show the flow of energy between organisms and visually represent who eats whom in a habitat. Several organisms can have the same food source. An organism can even hold several feeding positions of primary and secondary consumer (or secondary and tertiary consumer), depending on which food chains they are part of.

It is rare for an organism to rely on only one food source—if it did, then it may not survive if that food source disappeared due to disease, seasonal changes or a natural disaster.

For example, in Figure 6.7.2, the snake can eat mice, frogs or lizards. If, for example, the frogs disappeared, the snake could still eat mice and lizards to survive.

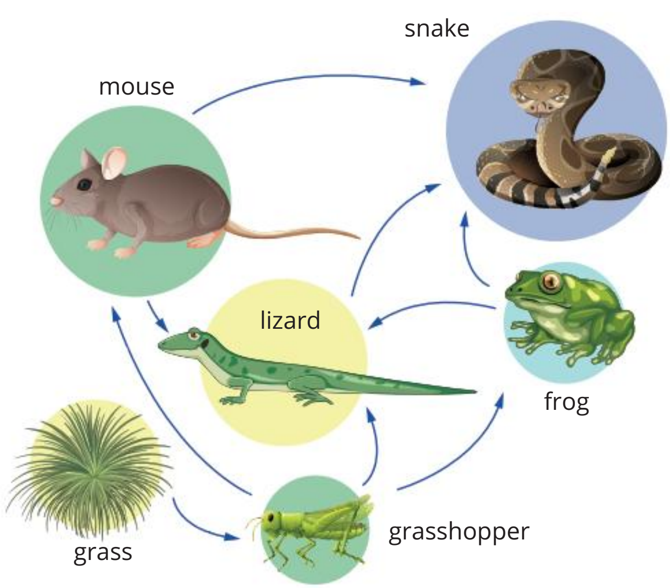
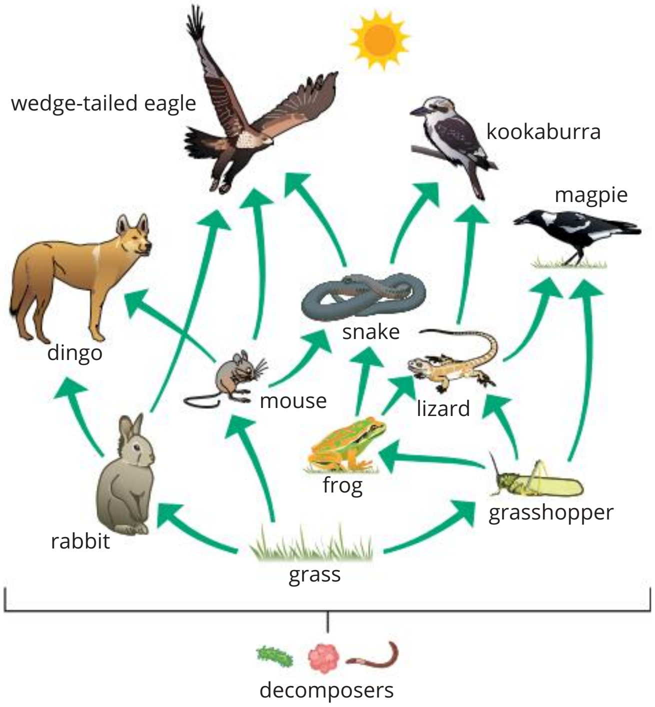


FIGURE 6.7.2 Many simple food chains can interconnect to create a more complex food web.

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.



The primary energy source in a food web is the Sun. The Sun provides the energy that helps plants, the producers, make their own food.

Apex predators are at the top of the food web. They have no natural predators, except humans.

- Tertiary consumers eat secondary consumers.
- Secondary consumers eat primary consumers.
- Primary consumers gain their energy from eating producers.
- Producers are at the base of a food web and provide energy for the primary consumers.

When organisms die or produce waste, decomposers break down this material and return the nutrients to the soil. These nutrients are then reused by the producers.

FIGURE 6.7.3 This food web shows the flow of energy in a eucalypt woodland.

Apex predators

Apex predators are at the top of the food web. They have no natural predators, except humans.

Energy pathways in food webs

Food chains typically involve four or five steps because too much energy would be lost if there were too many feeding levels.

Food chains and food webs

Two of the food chains within the food web shown in Figure 6.7.3 are:

grass → grasshopper → frog → snake → wedge-tailed eagle

grass → mouse → snake → wedge-tailed eagle

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

Identify the primary energy source in a food web.

SC 3 I can use relationships from a food web, and the concept of competition, to predict the effect of population changes within an ecosystem

Predicting the effect of population changes using food webs

Population changes occur in ecosystems for a variety of reasons including:

- seasonal changes
- the introduction of a species that is not native to the area
- predator–prey relationships (Figure 6.7.4)
- **climate change**
- disease
- natural habitat change (such as a fallen tree)
- human-caused changes (such as adding fertilisers to lawns near waterways).

These changes in the ecosystem may cause population increases, decreases or the disappearance of an organism from the ecosystem altogether.

It is for this reason that there are a variety of organisms in an ecosystem; in other words, a biodiverse ecosystem is a healthy ecosystem. For example, in an ecosystem that has greater biodiversity, if one food source is in short supply, another food source can be found and used by the organism that needs it.

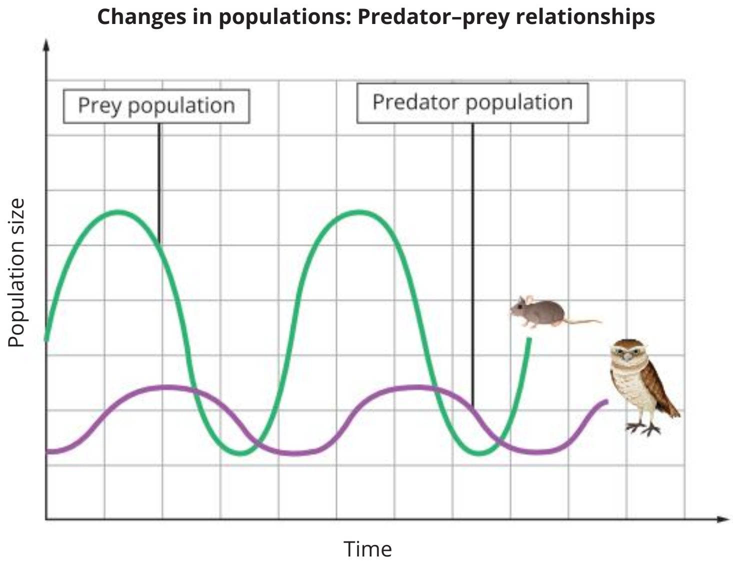


FIGURE 6.7.4 The graph shows that there is almost always more prey than predators: when predators are greater in number, prey decreases; when predators are lower in number, prey increases.

KEY TERM

climate change long-term changes in climate, including temperature change and weather patterns

Scifile

Omnivorous bears

In Alaska, climate change is causing berries to ripen earlier in the season, causing bears to switch their diet from salmon to berries. This shift affects the salmon population as well as scavengers who normally rely on the carcasses of the fish left behind by the bears.

GO TO

Toolkit section 3.5, Patterns and trends in data

Competing for food

Food webs have many organisms that eat the same type of food or prey. In Figure 6.7.5, foxes compete with owls for mice. What would happen to the fox if there were fewer mice available? It could be assumed that the fox would eat more rabbits, and this would reduce the rabbit population. This might result in an increase in the amount of grass available as there would be fewer rabbits eating the grass.

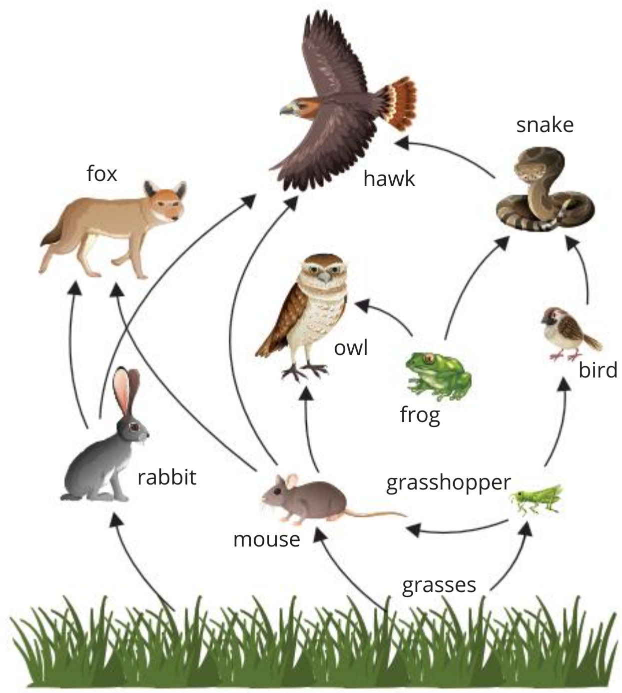


FIGURE 6.7.5 Food webs are complex and can affect many organisms in an ecosystem.

SC 3 CHECK YOUR UNDERSTANDING

Using Figure 6.7.4 and Figure 6.7.5, explain what would happen to the mouse population if the number of owls increased.

Lesson review

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

1. Explain what is shown in a food web.
2. Explain why food webs in a rainforest are more complex than food webs in a desert ecosystem.
3. Describe competition in an ecosystem.
4. Creating food webs helps understand the interactions and energy flow in an ecosystem.
   a. Describe the steps needed to create a food web.
   b. Identify the key producers and consumers in a coastal ecosystem.
   c. Draw the food web based on the identified feeding relationships in part b.
   d. Explain the importance of each trophic level in maintaining the ecosystem's balance.
5. Predict how an increase in the population of a primary consumer may affect the food web in a grassland ecosystem.

6.8 Food web in an Australian 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 (Figure 6.8.1). 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.

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.

FIGURE 6.8.1 Marine scientists observe the feeding relationships in the ocean.

Background

There is a complex network of organisms living all around you—even in your backyard. 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.

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?

Aim

To conduct a survey of a local ecosystem and construct a food web to represent the feeding relationships between the organisms that live there

Materials

Write a materials list for your investigation.

SAFETY NOTE

- Write safety notes for your investigation. Think of three or four different aspects of your investigation that might need some more careful consideration.

GO TO
Toolkit sections 2.1, Writing a method for an experiment and 5.4, Graphic organisers

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

Working in a small group of three or four students, write a method for your investigation.

Remember that 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 one of:
   - producer
   - herbivore (primary consumer)
   - carnivore (secondary consumer)
   - carnivore (tertiary consumer)
   - omnivore
   - 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.

Conclusion

1 How does the food web you created help you understand 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.

Evaluation

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.

6.9 Habitat destruction and pollution

Lesson overview

Throughout history, humans have lived within ecosystems, often unaware of how their actions disrupt the balance of abiotic and biotic factors. Today, a deeper understanding of the natural world allows for more informed choices and efforts to correct past mistakes, helping to preserve the environment for future generations.

As societies have developed, people have become less connected to nature and more dependent on exploiting natural resources. Many Australians have opportunities to work with scientists, governments and First Nations Australians to share knowledge and influence environmental outcomes.

In this lesson, you will explore the shared responsibility of protecting the planet for future generations. It also examines how First Nations Australians provide valuable knowledge for rebuilding a sustainable and respectful relationship with nature.

Learning intention

To understand how human use of the environment can cause habitat damage or destruction

Success criteria

SC 1: I can explain how farming practices can affect ecosystems.

SC 2: I can explain how First Nations Australians' traditional knowledge can inform sustainable harvesting practices.

SC 3: I can describe examples of chemical pollution caused by agriculture, industry and urbanisation.

SC 1 I can explain how farming practices can affect ecosystems

Farming, which began over 12 000 years ago, has evolved into a global practice. Today, food supplies rely heavily on intensive farming methods. These are designed to boost efficiency in production within a very limited land area to reduce costs for farmers. Farming practices include the use of advanced technology, mechanisation, increased chemical application, specialisation and government policies.

For example, modern tractors (Figure 6.9.1) can prepare fields much faster than manual labour can. This significantly reduces time and labour costs. However, these intensive practices can have adverse effects on soil structure, water supplies and the integrity of the environment. To counteract these consequences, additional measures, such as the application of chemicals and fertilisers, are often employed.

FIGURE 6.9.1 A tractor working on a field

Scifile

Food waste

In Australia, about 35% of food production every year goes to waste. While boosting food production is vital for enhancing food security, it should also be coupled with sustainable and quality-focused practices to reduce food waste and guarantee the nutritional value, safety and overall quality of the food supply.

Alternatives to intensive farming practices

Many people are now choosing food that is grown without harmful chemicals and without a significant negative impact on the environment. As a result, there have been an increasing number of farmers that have turned to more sustainable food production practices.

Permaculture

Permaculture principles focus on designing **agricultural** systems that align with nature and promote biodiversity. This adaptable approach can be applied across various Australian environments, from arid zones to temperate regions (see Figure 6.9.2).

Organic farming

Organic farming practices avoid synthetic pesticides and fertilisers. By doing this, organic farming safeguards the natural environment, promoting healthier soils and reducing chemical contamination (Figure 6.9.3).

KEY TERM

agricultural relating to the practice of growing plants and animals to make food

FIGURE 6.9.2 An organic permaculture garden with a variety of species

FIGURE 6.9.3 Changes to the chemicals used in pesticides and fertilisers used in large-scale crops can assist in ensuring the health of the environment.

SC 1 CHECK YOUR UNDERSTANDING

Intensive farming is commonly used in society.

a Describe intensive farming.

b List some practices that are commonly used in intensive farming.

SC 2 I can explain how First Nations Australians' traditional knowledge can inform sustainable harvesting practices

When the First Fleet arrived in Australia in January 1788, European settlers encountered a vastly different climate and landscape from their homeland. Their existing tools, farming methods, crops and livestock were not suited to the challenging and comparatively barren conditions of the Australian environment. However, First Nations Australians have expertly managed the land and environment through sustainable practices for millennia (tens of thousands of years). These practices include crop cultivation, fish-trapping and cultural burning (also known as cool burning or firestick farming) (Figure 6.9.4).

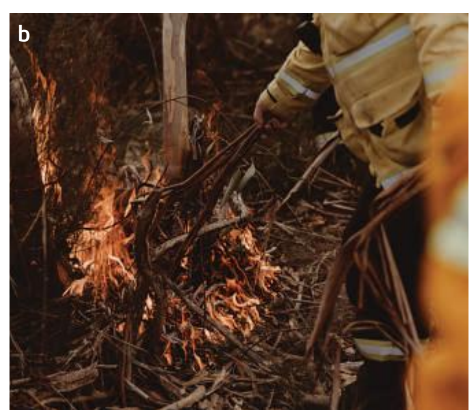


FIGURE 6.9.4 **(a)** A Bindarray, Walbunja fire practitioner, demonstrates how to spark up a patch of native forbs and grasses; **(b)** A traditional firestick using pieces of stringy bark to light a mosaic of cultural burning fires.

The farming techniques of First Nations Australians aim to encourage new growth in native plants, facilitate hunting and enhance the food supply for their communities. First Nations Australians have adapted their practices over millennia to harmonise with the land, while the newcomers struggled to apply their methods to the harsh Australian terrain.

For example, the regular use of cultural burns transforms scrublands into grasslands, changing the composition of local plant and animal species. It fosters edible ground-level plants (e.g. bush potatoes) and populations of grass-eating species (e.g. kangaroos) to regenerate or repopulate the ecosystem.

Incorporating First Nations' knowledge into modern practices can provide more sustainable alternatives while harnessing the potential of seemingly inhospitable regions for agriculture. The following examples explore First Nations knowledge in more depth.

Flour production

First Nations peoples of Australia once managed and cultivated vast grain belts covering most of the continent. These regions provided fertile ground for grain harvests, used in turning wild seeds into flour over 30 000 years ago (Figure 6.9.5). By incorporating First Nations knowledge into modern agricultural practices, farmers can gain the potential knowledge to manage different types of land in order to produce sustainable harvest.

FIGURE 6.9.5 Grinding stones like this were found at Cuddie Springs archaeological site in western New South Wales; these were used to create grind seeds into a flour-like substance.

Traditional Australian bush foods

While there are over 6500 native food varieties in Australia, only 13 have received certification from Food Standards Australia New Zealand (FSANZ) for development in local and international markets. Recently, however, there has been a surge in the commercial cultivation of traditional Australian bush foods, known for their resilience in the arid Australian climate. Some examples are lemon myrtle, Kakadu plums, quandongs and wattle seed (Table 6.9.1).

TABLE 6.9.1 Images of native Australian busk tucker

lemon myrtle	Kakadu plums	quandongs
		

This trend represents a growing interest in embracing First Nations agricultural practices, as well as an appreciation of First Nations traditions and flavours in promoting a sustainable food future.

SC 2 CHECK YOUR UNDERSTANDING

State two examples of First Nations' farming practices.

Scifile

Modern bush tucker

Incorporating bush tucker into traditional recipes, like baked cheesecake containing wattle seeds, is one example of how First Nations food knowledge may be leveraged.

SC 3 I can describe examples of chemical pollution caused by agriculture, industry and urbanisation

Examples of chemical pollution

For thousands of years, human activities have disrupted ecosystems through habitat destruction, pollution and invasive species. Unlike other species, humans reshape the environment to meet their needs through urbanisation, mining, agriculture and industrial development. The long-term consequences of these actions, including biodiversity loss, are only now being fully recognised.

Industrial activity, urbanisation and agriculture have played a major role in shaping the environment. As understanding grows, many governments and businesses are shifting to sustainable practices to reduce long-term environmental impact.

FIGURE 6.9.6 A dead northern gannet has plastic fishing net wrapped around its beak. Animals affected by plastic in the marine ecosystem include birds, seals, fish and turtles.

Industry

One striking example of chemical pollution caused by industry is the amount of microplastics in the environment. Microplastics are tiny plastic particles formed by industrial processes and the breakdown of larger plastic items such as water bottles, textiles and cosmetics. Taking hundreds of thousands of years to decompose, microplastics pose a severe threat to ecosystems and animal health as they enter the food chain. Plastic waste produced by industry can have severe and long-term effects on the environment even before it breaks down as large plastic pollution can choke and entangle animals (Figure 6.9.6).

FIGURE 6.9.7 This owl was poisoned after consuming a rodent that had ingested bait

Urbanisation

Increasing urbanisation has led to an increase in pest species such as rats and mice in residential areas. To control these rodents, poison baits called rodenticides are commonly used. However, these toxins build up within individual animals in a process known as **bioaccumulation**. Additionally, when predators consume poisoned rodents, the toxins pass along the food chain and become more concentrated at higher levels, a process known as **biomagnification**. These chemicals can persist in the environment, affecting many species over time.

This results in harm to unintended targets higher up the food chain, including owls (Figure 6.9.7), hawks, eagles and even pet cats and dogs.

KEY TERMS

bioaccumulation when harmful chemicals or pollutants build up in the bodies of organisms over time

biomagnification when a harmful chemical builds up in organisms as it travels up the food chain

Agriculture

The use of chemicals in agriculture, such as certain herbicides, has raised concerns about their environmental and health implications. Some herbicides, sprayed on genetically modified crops like corn, canola and soybeans, has been linked to soil degradation and water contamination (Figure 6.9.8). Furthermore, the health risks associated with exposure to certain herbicides have fuelled ongoing debates, with some studies suggesting there could be a connection to certain cancers and disruptions in the body.

FIGURE 6.9.8 A herbicide is sprayed over a field of barley before harvesting.

Excess fertilisers that run off into rivers and lakes can cause algal blooms (Figure 6.9.9) which starves aquatic organisms from the oxygen they need to breath and survive. Another effect of chemical pollution is **eutrophication**, which is when a body of fresh water ends up with too many nutrients, usually from fertilisers or waste.

There are many other examples of chemical pollution damaging ecosystems, and problems with commercial waste products are still being discovered. Chemical pollution affects many aquatic environments. Chemical pollutants like nitrogen, phosphorus or sulfur can cause waterways to become more toxic or acidic, which leads to species decline.

KEY TERM

eutrophication the accumulation of nutrients in a body of water

FIGURE 6.9.9 The algal blooms in this freshwater river ecosystem are a response to increased nutrient levels from fertiliser run-off.

It is important that people consider the potential impact of their choices, and make careful, well-informed decisions about what to support through purchasing behaviour. Balancing industry and sustainability is essential for preserving the natural world and maintaining biodiversity.

SC 3 CHECK YOUR UNDERSTANDING

Describe some effects of chemicals on the ecosystem.

Lesson review

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

1 Outline one intensive farming practice that can damage ecosystems.

2 Intensive farming practices can have significant effects on ecosystems.
   a Describe the main features of intensive farming practices.
   b Explain how these practices can lead to habitat damage.
   c Discuss the impact of intensive farming on local wildlife populations.

3 Identify one example of chemical pollution from agriculture.

4 Draw a table to compare the sources and effects of chemical pollution from agriculture and urbanisation on aquatic ecosystems.

6.10 Detergents in waterways

Learning intention

To be able to develop hypotheses to test relationships

Success criteria

SC 1: I can write a hypothesis and a prediction for an investigation that tests the relationship between the abiotic and biotic factors in an ecosystem.

SC 2: I can plan and conduct a reliable and valid investigation to determine the effects of detergents on aquatic plants.

SC 3: I can identify relationships between biotic and abiotic factors in an ecosystem from experimental data and evaluate the quality of a conclusion.

FIGURE 6.10.1 Everyday products affect local plant life and ecosystems.

GO TO
Toolkit section 1.3, Hypotheses and predictions

Introduction

Detergents are found in cleaning products that are widely used in households and industry. Products like laundry and dishwasher powders and liquids have chemicals that are toxic to aquatic life. These products can enter waterways through stormwater and sewage systems, devastating aquatic ecosystems. Phosphates in detergents can cause algal blooms in freshwater environments, and surfactants (substances in detergents that increase their spreading and wetting properties) can damage the cell membranes of plants and animals.

In this practical investigation, you will design an experiment to test the effect of detergents on aquatic plants.

Background

Aquatic plants are plants that live in, under or on top of the water. In this investigation, you will collect data to determine if the soap you wash your hands with several times a day, the detergent your clothes are washed in, or the soap you use in the shower is damaging these plants (Figure 6.10.1).

Aim

To design and conduct an experiment to investigate the effect of detergents on aquatic plants

Hypothesis

Write a hypothesis for your investigation.

Remember that a hypothesis is a statement about the relationship between two variables, which can be tested experimentally. It should also include the independent variable (what is being changed in the experiment) and the dependent variable (what is being measured).

Before writing your hypothesis, think about how detergents entering waterways might affect the plants in those environments. Refer to the introduction to this lesson for some ideas.

Method

1 Working in a small group, discuss ways to investigate the effects of detergents on aquatic plants in a laboratory.

2 Choose the idea that is likely to result in the most valid and reliable data with the time and resources you have available.

3 Design a method to determine the effect of detergents on aquatic plants. Write out your procedure as a list of steps that each begin with a verb. Ensure you include the necessary equipment and safety considerations.

4 Check your procedure and safety measures with your teacher before continuing.

Materials

Write a materials list for your investigation based on your chosen method. Include all equipment and substances—and the quantities—required.

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

Record your results.

When drawing a table of results, it should include a:

- descriptive title that includes the independent and dependent variables
- heading for the independent variable, including units if appropriate
- heading for the dependent variable, including units if appropriate.

Example table of results:

Title:____

Detergent (%)	Mass of the plant (g)			
	Day 1	Day 3	Day 5	Day 7
0				
2				
4				
6				

Conclusion

1 Write a conclusion for your investigation.

2 Was your hypothesis supported or not supported?

Remember to add data to your conclusion.

Evaluation

Discuss the strengths of the procedure used and propose ideas for improvement. Make note of three strengths and three areas for improvement for the procedure used.

HINTS

A valid experiment tests only one independent variable and has controlled or constant variables so that it measures what the aim intends.

A reliable experiment is one that can be repeated to produce consistent results each time.

HINT

Remember to include one set-up without any detergent as a control so that you can compare the other plants to this. Make clear how you will measure the effect of the detergent on the aquatic plants.

SAFETY NOTE

- Write safety notes for your investigation. Note that some detergents can be irritating to skin and eyes.

6.11 Desalination

Learning intention

To understand how desalination plants impact local marine ecosystems

Success criteria

SC 1: I can describe the process of desalination and how waste is produced.

SC 2: I can describe the effects desalination plants have on local marine ecosystems.

Lesson overview

Desalination plants are facilities that remove salt and other minerals from seawater, making it safe to drink and use for irrigation, industry and agriculture. These factories are usually built in places where fresh water is not readily available. While desalination plants can help reduce the pressure on other freshwater resources, they can also have negative impacts on the local marine and aquatic ecosystems.

In this lesson, you will learn about the impacts that desalination plants have on local marine ecosystems.

SC 1 I can describe the process of desalination and how waste is produced

Desalination plants are becoming more popular. There are about 15 000 plants around the world and about 270 in Australia (Figure 6.11.1).

They are used in areas where freshwater resources are scarce, such as arid regions or coastal regions and islands, because they can provide a more reliable source of fresh water that is not dependent on rainfall alone.

Desalination is the process of removing minerals, mostly salt, from seawater through physical and chemical processes to make it safe to drink and use for **irrigation** and other purposes. There are several methods of desalination, but the most common method and the one that uses the least energy is a process called reverse osmosis. Reverse osmosis pushes water through a super-fine filter, allowing some substances to get through and others not.

KEY TERMS

desalination removing dissolved salts such as sodium chloride from water

irrigation used in agriculture to provide water to crops

FIGURE 6.11.1 The Victorian Desalination Plant, Wonthaggi, Victoria

In Australia, the process of desalination involves a variety of steps in order to make the water removed from the ocean both drinkable and ready for use (Figure 6.11.2).

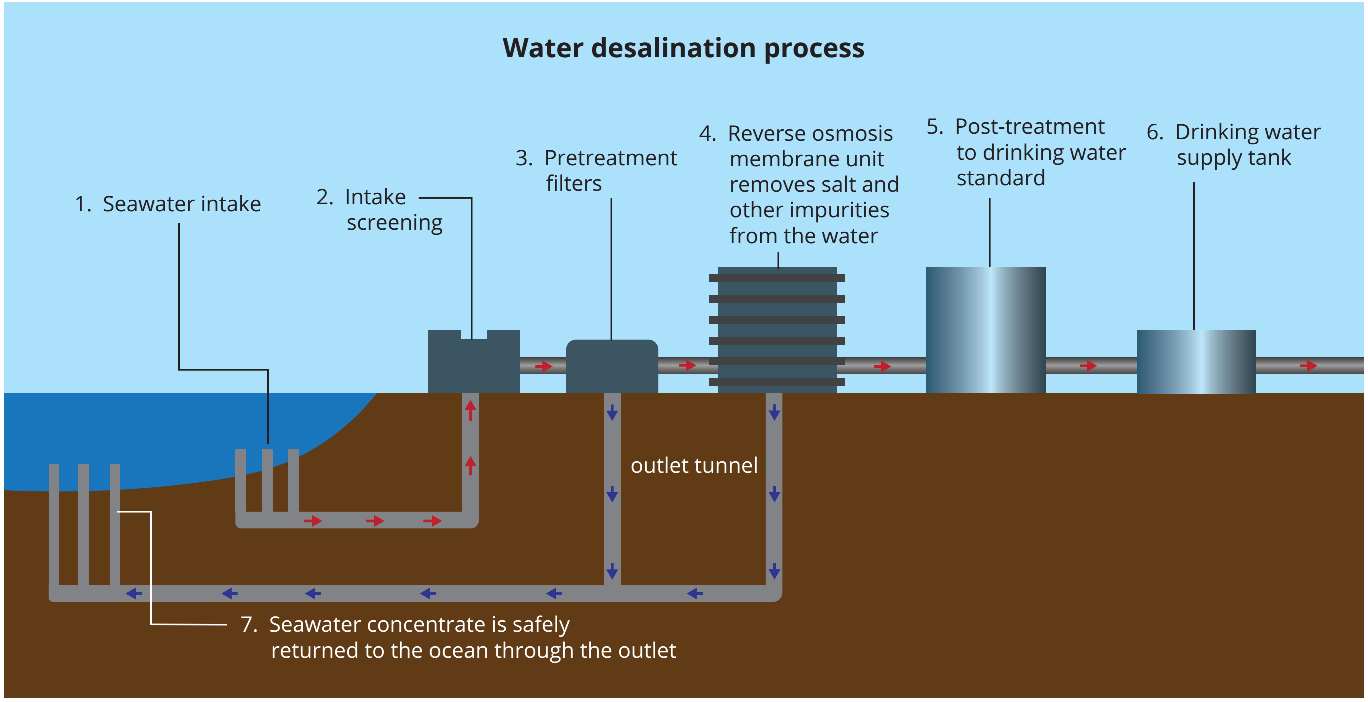


FIGURE 6.11.2 There are six steps to the reverse osmosis desalination process.

Screening and pretreatment

Seawater is passed through large concrete tunnels very slowly. Drum screens or filters remove large solid items, such as pollution, seaweed and shells. The water is then passed through layers of filter coal and sand.

High-pressure pumping

The seawater is then pressurised and pumped through a filter that allows certain substances to pass through while blocking others based on their size, charge or other properties.

Desalination

The salt and other minerals in the seawater are unable to pass through the membrane, while the fresh water can. This process leaves the seawater on one side of the membrane, and the fresh water on the other side. The water that is left behind is much saltier than the initial seawater.

Post-treatment

The fresh water may be further treated to remove any remaining impurities. At this stage, the pH may be adjusted and other chemicals added. The water is then stored in large water tanks.

FIGURE 6.11.3 Desalination must consider the surrounding marine life when disposing of the leftover brine.

Desalination waste

The main waste generated by desalination plants is called brine, a salty seawater concentrate. The seawater concentrate is sent out to sea through outlet tunnels. In most cases, the saltier water is sent out through nozzles that help it mix quickly in the natural seawater to make sure that it does not affect the local marine environment.

However, the discharge location, timing and volume of seawater concentrate needs to be carefully monitored to prevent negative impacts on the marine environment and coastal ecosystems (Figure 6.11.3).

SC 1 CHECK YOUR UNDERSTANDING

List the key steps involved in the desalination process.

SC 2 I can describe the effects desalination plants have on local marine ecosystems

Desalination plants can have negative effects on local marine ecosystems (see Table 6.11.1). The waste product of the desalination process, seawater concentrate (or brine), has a higher salt concentration than the original seawater. When this brine is discharged back into the ocean, it can have negative impacts on the marine environment. The high salinity and higher temperature of the brine in comparison to seawater can be toxic to certain marine species, reducing local populations and biodiversity.

TABLE 6.11.1 Marine ecosystems at risk from the effects of desalination plants

Mangrove forests

Mangrove forests play an essential role in coastal ecosystems. They also help to protect coastal areas from erosion and storms.

Desalination plants can change the flow of water, temperature, and levels of dissolved oxygen and other chemicals in the water.

Coral reefs

Coral reefs are delicate and complex ecosystems. They are also important for protecting coastlines from erosion and storms.

The discharge of brine can be harmful to coral reefs, as the high salt concentration can change the chemistry and temperature of the water.

Seagrass beds

Seagrass beds are underwater meadows of marine flowering plants. They play a vital role in coastal ecosystems as they provide food and habitats for many marine species. They also help to improve water quality.

Desalination plants can affect the growth of seagrasses.

Other potential aspects of using desalination plants for drinking water are the disruption of marine animal behaviour, discharge of seawater concentrate increasing the temperature and decreasing quality of seawater as well as impacting the structure of the seabed (see Table 6.11.2).

TABLE 6.11.2 Negative impacts of desalination plants

Taking water from the ocean	Underwater noise	Energy demand
Large amounts of seawater that are constantly being pumped from the ocean can reduce the water level of the ocean around the plant. This affects the surrounding habitat and can alter the **migration patterns** of aquatic species in the area.	The underwater noise and vibrations generated by desalination plants can have harmful impacts on marine life. For example, the noise pollution created by desalination plants can disrupt the communication, feeding and mating behaviours of marine mammals such as dolphins and whales.	The energy demands of desalination plants have a range of broader environmental impacts because many desalination plants require large amounts of energy to operate. This can increase their impact on **greenhouse gas** emissions and air pollution. There is a push to use more sustainable energy sources in powering desalination plants.
		

SC 2 CHECK YOUR UNDERSTANDING

Outline two ways that desalination plants affect marine ecosystems.

KEY TERMS

migration pattern the regular route that animals travel from one place to another, often because of seasonal changes

greenhouse gas a gas that traps heat close to Earth's surface

Lesson review

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

1. Define desalination.
2. Describe how waste brine produced by desalination plants can affect local marine ecosystems.
3. Explain why desalination plants are becoming more popular.
4. Identify ways that water from the desalination process can be used.
5. Construct a method you could use to investigate the impact of a desalination plant on local fish populations.

6.12 Cultural understandings and sustainable practices

Learning intention

To understand how First Nations Australians use deep ecological understanding to develop sustainable practices

Success criteria

SC 1: I can explain how First Nations Australians' deep ecological understanding can inform sustainable practices.

SC 2: I can name various sustainable practices used by First Nations Australians.

SC 3: I can explain how First Nations Australians' practices have influenced scientific knowledge about ecosystems.

Lesson overview

First Nations Australians have a deep spiritual and cultural connection to the land that emphasises the interdependence of all living things in the environment. Everything in the environment is considered equally important. This means that a bird or an ant in a food chain is appreciated for the unique and important role it plays, without prioritising one organism over another. This respect is founded on the knowledge that everything in nature is connected; humans are part of one vast system and its wellbeing depends on the health of all its individual parts.

First Nations Australians have a particularly strong connection to their ancestral lands or Country, which is central to both their identity and belonging. Their deep ecological understanding is a result of many thousands of years of observation and interaction with their environment.

In this lesson, you will explore how First Nations Australians apply their deep ecological insights to develop sustainable practices.

SC 1 I can explain how First Nations Australians' deep ecological understanding can inform sustainable practices

First Nations Australians have developed a deep **ecological** wisdom through their enduring connection to the land. First Nations peoples used their traditional knowledge to grow crops, make traps for fishing and utilise practices passed down over many generations (Figure 6.12.1). This is embodied in **Creation stories** and **Traditional Lore**, which provide a holistic and sustainable approach to environmental management and resource use. Many First Nations people moved around their lands seasonally, sometimes for trade and cultural reasons (such as ceremonies). People in harsher climates tended to move around their lands more, whereas those whose lands contained rich resources developed more permanent settlements.

First Nations communities can offer invaluable insights in shaping modern sustainability practices for ecological management.

FIGURE 6.12.1 These siblings are fishing at Mukkamukka, a billabong in Arnhem Land

KEY TERMS

ecological relating to ecosystems or interactions between living things and their environment

Creation stories stories that explain the origins of the universe, the rules for living and the relationship of people to each other and the environment; also known by many as Dreaming stories

Traditional Lore all the old stories, beliefs and customs that people pass down through generations; includes myths, legends, fairy tales, and ways of doing things that have been around for a long time

The Creation

First Nations Australians have a deep understanding of Australian ecosystems. All elements of the natural world are intricately interconnected and hold **spiritual** significance in the Creation stories of First Nations Australians.

Creation is not confined to a distant past; it includes the past, present and future. Deeply rooted in the Earth, it continues to be a guide for many First Nations people today. Specifically, Creation is a spiritual and cultural framework that guides practices like resource use and land management, that helps to create innovative and regenerative solutions to environmental issues through art and story (Figure 6.12.2).

KEY TERMS

spiritual relates to the soul or spirit or religious beliefs

Creation the concept that encompasses the belief systems that bring together spiritual and physical knowledges for First Nations Australians; also known by many as the Dreaming

FIGURE 6.12.2 A serpent painting from Central Australia

First Nations people use storytelling to show closely held beliefs about Country and the natural environment. Creation stories place a strong emphasis on respect for all species and the need to understand the consequences of human actions on the natural world. These teachings may be seen in practices such as controlled burns for land management and resource conservation, the use of natural materials, and a commitment to living in harmony with the environment.

Traditional Lore

Traditional Lore refers to the beliefs, stories, customs and spirituality of First Nations Australians that has been passed down through generations. It affects the relationships people have with each other the environment and their totems.

Traditional Lore recognises that humans have a significant effect on the environment, both positive and negative. Therefore, lore guides behaviour around everyday life and cultural obligations, including family and marriage, ceremonies, land management, the division of labour, conflict resolution and the sharing of knowledge. Any problems are resolved by Elders. For the environment, Traditional Lore provides practical guidance, including sustainability principles, to maintain a balanced relationship between human activities and the natural world.

KEY TERM

sacred to have great cultural or spiritual significance

Connection to Country and Traditional Lore

The strong connection to Country, includes all living beings and the land, rocks and waters that are regarded as **sacred**. The lore serves as a guiding principle for the spiritual wellbeing of First Nations communities. This deep respect fosters sustainable practices, reinforcing the belief that human actions must safeguard the environment's harmony and equilibrium (balance).

Traditional Lore provides the guidelines for the critical practice of ongoing environmental assessment to ensure that the ecosystem remains in balance. The guidelines prevent the over-harvesting of resources and extinction of organisms, and is especially important during times of change. For example, First Nations people replanted the crown of bush yams to ensure they had crops for the next harvest (Figure 6.12.3).

FIGURE 6.12.3 The freshly harvested edible tubers of the yam daisy or murnong are an Australian native bush food.

Intergenerational responsibility

Traditional Lore also highlights intergenerational responsibility, which means learning from ancestors, respecting Elders and understanding how actions today may affect the wellbeing of future generations. This understanding informs sustainable practices that help protect the environment for future generations.

The traditional practice of using bark from trees to construct canoes is an example of intergenerational responsibility (Figure 6.12.4). Bark is removed in a way that allows the tree to keep growing, ensuring that the tree and anything it produces is available for future generations.

FIGURE 6.12.4 A swamp mahogany fishing canoe made by Gubbi Gubbi (Kabi Kabi) Elder Lyndon Davis to demonstrate traditional construction techniques

SC 1 CHECK YOUR UNDERSTANDING

Discuss how the deep ecological understanding of First Nations Australians is valuable for modern sustainability efforts.

SC 2 I can name various sustainable practices used by First Nations Australians

Over more than 65 000 years, First Nations Australians have used their comprehensive knowledge to shape the land in response to changes in society and the environment. Some of these practices are seasonal harvesting that aligns with natural cycles of the land, cultural burning, sustainable fishing, construction using sustainable materials, waste management, water and land conservation (Figure 6.12.5).

FIGURE 6.12.5 These Luritja women are working with local, renewable resources for food preparation

Table 6.12.1 summarises various sustainable practices used by First Nations Australians.

TABLE 6.12.1 Sustainable practices used by First Nations Australians

Resource conservation and land management	Resource use is based upon seasonal and location-specific knowledge, ensuring that fishing, hunting and plant gathering align with natural cycles. This includes use of controlled burning, natural materials, responsible use and careful harvesting of crops to promote regeneration of plants.	
Fishing	Fish traps were carefully constructed to allow large fish to enter but not exit, serving to catch the fish and encourage their breeding. This reduces the impact on wild fish populations.	
Agriculture	Agricultural methods include intercropping (cultivating multiple crops in the same area) and crop rotation (alternating the crops grown in a particular field over time) to maintain soil fertility and enhance agricultural productivity as well as employing eco-friendly pest and weed control methods to manage crop pests.	

Building	Building used natural materials to build shelters with materials like timber, stone and clay, which were readily available and well-suited for construction purposes. By using sustainable building materials, the need for artificial heating, cooling or lighting is minimised.	
Food production and harvesting	Harvesting of crops is done when resources are abundant and plentiful. This ensures that both breeding and growth seasons of native plants and animals are followed for the ecosystem to have sufficient time to regenerate. This practice supports regrowth while safeguarding biodiversity.	
Water management	Rainwater harvesting, wetlands management and restoration of damaged waterways ensured the health of aquatic ecosystems.	
Waste management	This includes composting, recycling and waste reduction; for example, using traditional techniques, like using natural materials for construction and crafting, to minimise waste generation.	

SC 2 CHECK YOUR UNDERSTANDING

State why traditional agricultural practices of First Nations Australians are considered sustainable.

SC 3 I can explain how First Nations Australians' practices have influenced scientific knowledge about ecosystems

KEY TERM

empirical observation
something you notice or learn by looking at the world around you, using your senses (e.g. seeing, hearing or touching), and collecting real, concrete information

First Nations Australians have made significant contributions to scientific developments, particularly in understanding Australian ecosystems. First Nations peoples followed scientific practices—continually hypothesising and experimenting on different aspects of plants and animals, making **empirical observations** and gathering evidence about patterns in the natural world.

First Nations peoples inferred and predicted environmental patterns to develop knowledge that helped them navigate Australia's harsh landscape. In the past, this knowledge was often ignored, exploited, or not recognised. Recognising and valuing it leads to a more inclusive and holistic approach to environmental research and conservation.

Table 6.12.2 provides examples of First Nations Australian practices and their impact on ecological management.

TABLE 6.12.2 First Nations Australian ecological management practice examples

Traditional practice	Description	Image
Land management	Knowledge of different Australian plants and their reliance on fire or smoke has informed modern conservation strategies and fire management.	
Biodiversity conservation	Conservation strategies that consider the cultural and spiritual significance of different species support the re-introduction and increase in populations in areas of concern as well as helping reduce introduced species.	
Climate change	First Nations peoples have lived through climate change before. Understanding the relationships between the environment, weather patterns and the health of ecosystems can influence scientific thinking about climate change.	
Traditional medicine	Using plants and other natural remedies for healing has influenced scientific thinking about the medicinal properties of plants and has contributed to the development of new treatments and medicines. Many plants used by First Nations Australians have **antibacterial** and **anti-inflammatory** properties.	

SC 3 CHECK YOUR UNDERSTANDING

Outline one way that First Nations peoples' actions or knowledge have influenced modern science.

KEY TERM

antibacterial a substance that kills bacteria

anti-inflammatory a substance that reduces swelling

Lesson review

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

1 List three sustainable practices developed by First Nations Australians.

2 Describe how one practice listed in question 1 is used by First Nations Australians.

3 Explain how an understanding of Creation informs sustainable practices.

4 Outline how Traditional Lore has influenced modern sustainable practices in Australia.

5 Compare one method of traditional First Nations practices with a non-traditional practice.

6 Matter and energy in ecosystems

Topic summary

The key concepts included in this topic are:

- All organisms require six basic needs to survive.
- Changes in populations are affected by biotic and abiotic factors.
- Australia has a range of aquatic and terrestrial habitats.
- Ecologists study the environment using research, observations and a variety of sampling techniques.
- Food chains and food webs represent the feeding relationships in an environment.
- Habitat destruction and pollution have a significant effect on the environment.
- First Nations knowledge is invaluable in ensuring the environment is not harmed.
- Desalination removes salt and minerals from seawater for human use but may have an impact on marine ecosystems.

Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

Remember

1 Identify the basic survival needs of plants in Australia.

2 List three different types of habitats in Australia.

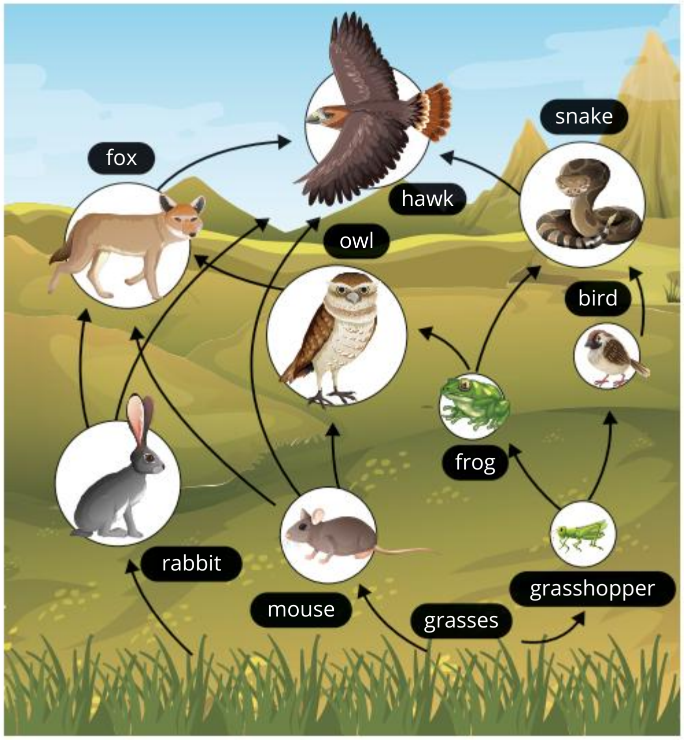
3 Name three specific threats to Australian ecosystems.

4 Define the term ‘biodiversity’.

5 Explain what a food chain represents and how it shows the flow of energy between organisms.

Understand

6 Using the grassland food web below, construct one food chain.



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 List three factors that contribute to species decline.

9 Explain one way Dame Jane Goodall's research has influenced conservation policies.

10 Describe how transects are used to observe the environment.

Apply

11 Using the grassland image, identify the producer, primary consumers, secondary consumers, and tertiary consumers in the food web.

12 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

13 Discuss the impacts of farming practices on ecosystems.

14 A student was investigating the effects of two types of laundry detergent on five aquatic insects in the local creek. They found that one insect population decreased from 10 organisms to three organisms, and another decreased from 20 organisms to 16 organisms in their sample.

a Identify the independent variable in this investigation.

b Identify the dependent variable in this investigation.

15 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 organism in their environment.

Extension: Research and create

16 You will use the internet and other sources to research and compare traditional First Nations medicines to those found in supermarkets or pharmacies. Then create a poster to advertise this medicine.

- Name one bush medicine and the health issues or problems it treats.
- Describe how First Nations people create the medicine and the process involved.
- Compare your chosen bush medicine to a similar medication found in supermarkets or pharmacies.
- 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.

6 Glossary

abiotic factor a non-living factor in the environment

adaptation a structure, behaviour or internal bodily feature of an organism that helps them survive

agricultural relating to the practice of growing plants and animals to make food

anti-bacterial a substance that kills bacteria

anti-inflammatory a substance that reduces swelling

apex predator a predator that has no natural predators except humans

aquatic in water environments such as ponds, lakes, oceans and seas

bioaccumulation when harmful chemicals or pollutants build up in the bodies of organisms over time

biodiversity the number and range of species that exist in an ecosystem, biome or biosphere

biomagnification when a harmful chemical builds up in organisms as it travels up the food chain

biomass all plant and animal matter on Earth

biomass pyramid a visual representation of the biomass at different levels of a food chain

biotic factor a living factor of the environment

carnivore a consumer that eats only other animals

climate change long-term changes in climate, including temperature change and weather patterns

community groups of organisms that interact within an ecosystem

competition a relationship between organisms that are trying to use the same limited resource

conservation the protection of resources, such as land and biodiversity

consumer an organism that must eat other organisms to get the energy and nutrients it needs

Creation the concept that encompasses the belief systems that bring together spiritual and physical knowledges for First Nations Australians; also known by many as the Dreaming

Creation stories stories that explain the origins of the universe, the rules for living and the relationship of people to each other and the environment; also known by many as Dreaming stories

decomposer an organism that gets the energy it needs by breaking down dead matter and waste products

desalination removing dissolved salts such as sodium chloride from water

ecological relating to ecosystems or interactions between living things and their environment

ecologist a scientist who studies the interactions between living things and their environment

ecology the study of how organisms interact with each other and with their non-living surroundings

ecosystem a system formed by organisms interacting with each other and their non-living surroundings

empirical observation something you notice or learn by looking at the world around you, using your senses (e.g. seeing, hearing or touching), and collecting real, concrete information

endangered species an animal or plant that is at serious risk of disappearing forever

environment all the factors in an organism's surroundings that affect its survival

eutrophication the accumulation of nutrients in a body of water

food chain the flow of energy from organism to organism in a series of feeding relationships

food web a diagram representing two or more connected food chains

genetic relating to heritable characteristics or features passed on from parent to offspring

greenhouse gas a gas that traps heat close to Earth's surface

habitat the place where an organism lives

herbivore an animal that eats only plants

irrigation used in agriculture to provide water to crops

mass the amount of matter in a substance or object; measured in grams (g), kilograms (kg) or tonnes (t)

migration pattern the regular route that animals travel from one place to another, often because of seasonal changes

omnivore an animal that eats both plants and animals

organism a living thing

population a group of organisms of the same species that 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 first-order consumer

producer an organism able to manufacture its own food; plants are producers

pyramid of numbers a diagram representing the number of organisms in an ecosystem

resource something that meets a particular need or fulfils a particular purpose

sacred to have great cultural or spiritual significance

sampling technique a 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 second-order consumer

spiritual relates to the soul or spirit or religious beliefs

sustainable using resources in a way that keeps Earth healthy for a long time

terrestrial on land

tertiary consumer a consumer that eats a secondary consumer; also known as third-order consumer

tolerance the ability of an organism to survive under particular conditions

Traditional Lore all the old stories, beliefs and customs that people pass down through generations; includes myths, legends, fairy tales, and ways of doing things that have been around for a long time

trophic level the position of an organism in a food chain

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