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Science

STUDENT BOOK | 3RD EDITION

8

AUSTRALIAN CURRICULUM



PEARSON

Science 8

STUDENT BOOK | 3RD EDITION



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

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

We pay our respects to Elders, past and present.

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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

The components of Pearson Science

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): 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.



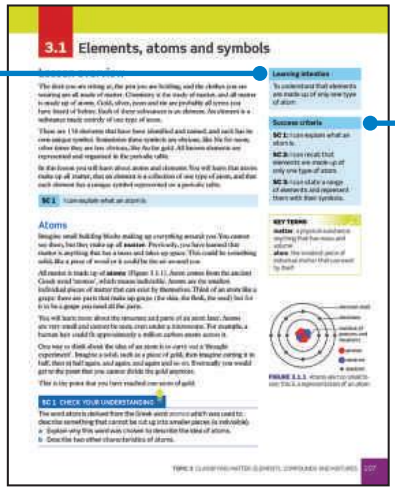
The Student Companion: a write-in workbook designed to reinforce the scaffolding of learning provided in the corresponding Pearson Digital Hub lessons. The Student Companion also supports the creation of a bound reference or portfolio of learning over the year.

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) has 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.



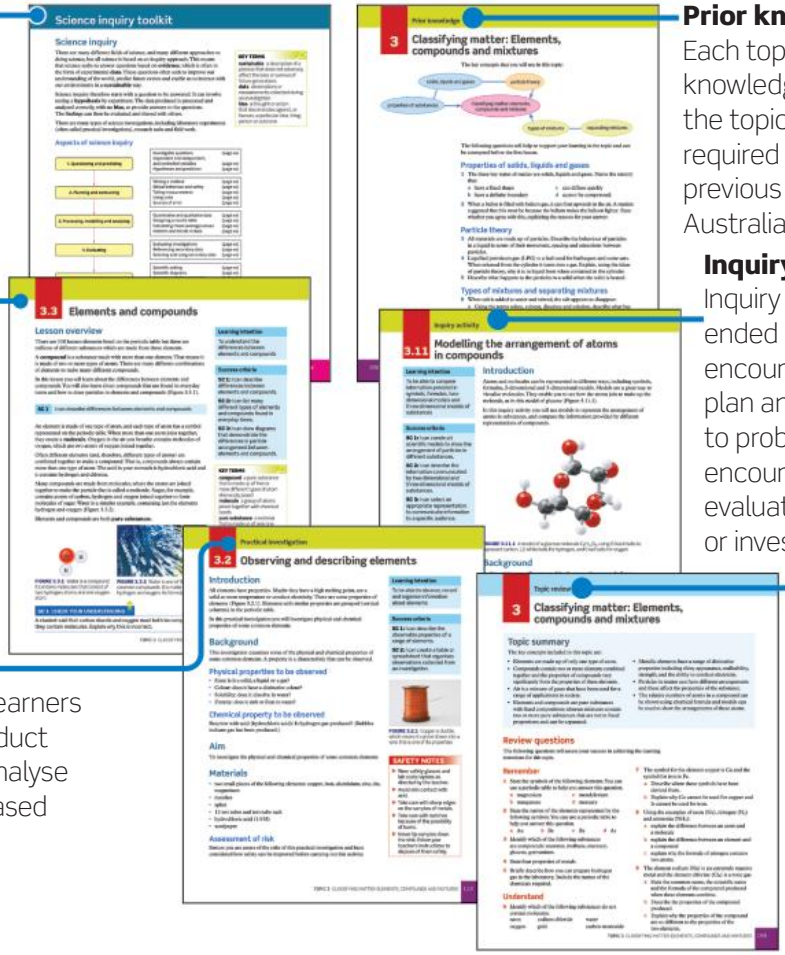
Success criteria clarify expectations and describe what success looks like. They are used to determine how well a student has met the learning intention. The Pearson Science lesson design is based on cognitive load principles and, as such, each lesson has 1–3 success criteria. The success criteria are 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

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

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



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

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

Topic review
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

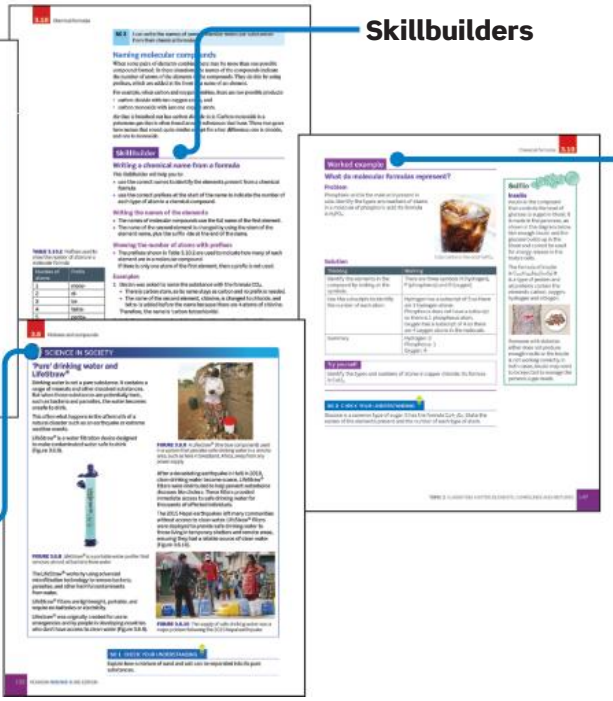
Scifiles

Science in Society boxes



Skillbuilders

Worked examples



Pearson Science 3rd Edition

For the Australian Curriculum 7–10 Science V9.0



eBook

Student Book

Pearson Digital Hub

Student Companion

Your complete science solution for Years 7–10—created by education experts to support every teaching style and every learning journey.

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

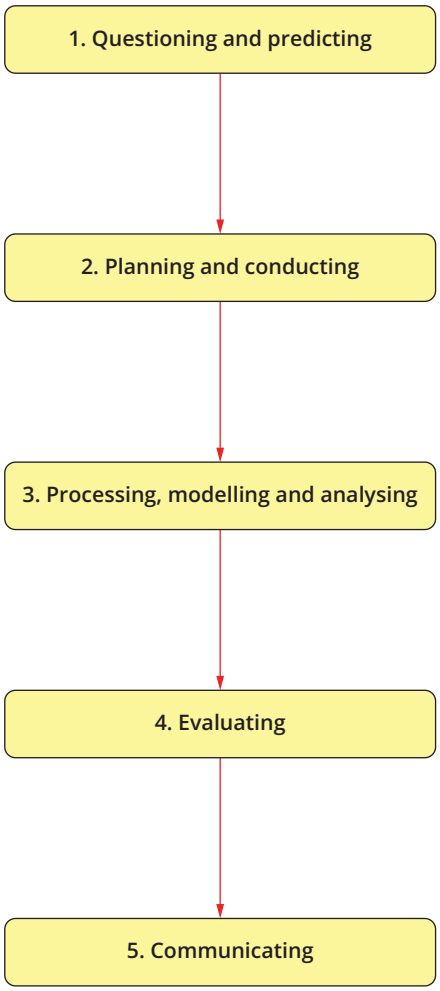
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Science inquiry

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, which is often in the form of experimental data.

In Year 8 you will be building on your Science Inquiry skills from Year 7, including applying them to new and more complex situations.



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The information and activities in this Science Toolkit will support your learning by describing, explaining and giving examples of science inquiry skills that you will use in Year 8. When carrying out practical investigations and inquiry activities, the knowledge and the skills included in this toolkit will help you to succeed with the activities.

KEY TERMS

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

correlation a relationship or connection between two or more variables

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

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

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

1 Questioning and predicting

1.1 Investigable questions: Cause and effect, and correlation

Cause-and-effect relationships and **correlation** are key concepts in scientific inquiry. While correlation refers to a relationship between two **variables**, it does not necessarily mean that one *causes* the other. Cause and effect, on the other hand, means that a change in the **independent variable** will result in change to the **dependent variable**.

There is in an important difference between correlation and cause and effect, as explained in Table 1.

TABLE 1 Comparing cause and effect to correlation

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

KEY TERM

hypothesis a statement about the relationship between two variables

Many scientific **hypotheses** are statements of possible cause-and-effect relationships. A well-designed investigation can be used to provide evidence for the cause and effect (see Toolkit section 3.1).

There is a risk when people use scientific data to support claims that they assume (either unintentionally or to deliberately misrepresent the data) that a correlation always is due to cause and effect.

An investigable question should be clear about whether it is a correlation, or a cause and effect, that is being tested.

1.2 Making predictions from observations

Observations can often lead to a question that can be answered by a scientific investigation.

To attempt to answer these kinds of questions, predictions can be made by applying prior knowledge or observations.

Using observations to make a prediction

Scientists use observations of past events (prior knowledge) to predict what will happen in similar situations in the future. Table 2 describes some of the considerations that need to be applied when using observations or prior knowledge to make predictions.

TABLE 2 Making predictions based on observations

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

Example

Ada wanted to drop different types of balls on different surfaces to test how high they would bounce. She found an experiment that students had conducted the year before and read their results (Table 3).

TABLE 3 Average height of bounce of different ball types on different surfaces

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

Ada wants to use these observations to predict on which surface a golf ball will bounce the highest. The thinking/working involved is shown in Table 4.

TABLE 4 Creating a prediction from observations

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

2 Planning and conducting

2.1 Reducing risk

KEY TERM
risk the possibility of something harmful occurring

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

Identifying risk

Before starting an investigation, it is important for your safety and the safety of others that you identify and reduce potential risk.

Consider the following checklist before conducting an experiment to ensure that all aspects of risk have been considered.

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

Reducing risk

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

Behaviour risk reduction

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

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

Example

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

Equipment risk reduction

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

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

Example

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

Substance risk reduction

When working with substances such as chemicals, take the following steps to reduce risk. Information is available in Safety Data Sheets (SDS) for each substance (Figure 1).

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

Example

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



FIGURE 1 It is important to check the Safety Data Sheets when working with substances such as chemicals.

KEY TERMS

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

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

2.2 Reproducible investigations

Imagine a scientist, or team of scientists, carrying out an experiment. Then imagine other scientists carrying out the same experiment. If the experiment is reproducible, the other scientists should obtain similar results and the same conclusions as the original experiment.

The idea of reproducible experiments is an important part of science inquiry because reproducing the experiment validates the **reliability** and **accuracy** of the findings.

The following is a guide to ensure that an investigation is reproducible.

- ☐ Start with a clear hypothesis or prediction.
- ☐ Include a detailed step-by-step method with all equipment, substances and quantities.
- ☐ Identify variables to be controlled.
- ☐ Describe how the independent variable will be changed.
- ☐ Describe how the dependent variable will be measured.
- ☐ Record all observations and measurements carefully, and include units.
- ☐ Have others review your method and results and make changes if needed.
- ☐ Present your findings clearly, using graphs and tables where appropriate.
- ☐ Include an evaluation that can identify problems and suggest improvements.

2.3 Sites on Country/Place

First Nations people of Australia have a profound connection to and responsibility for Country/Place. Country is a term often used by First Nations peoples to describe the lands, waterways, seas and skies they have a cultural connection to. These places may hold deep spiritual and cultural significance.

Within these areas, there are specific heritage sites that hold special meaning for First Nations people. The laws governing access to these sites are managed by state and territory governments, who collaborate with First Nations peoples to identify and protect them. These heritage sites are listed in online databases, such as the Queensland Aboriginal and Torres Strait Islander Cultural Heritage Database and Register, and in South Australia, the Register of Aboriginal Sites and Objects, which forms part of the state's Central Archive.

When conducting scientific fieldwork, identifying cultural heritage sites is crucial. These sites may include ceremonial grounds, traditional work sites, rock art, ancient caves, burial sites, waterways and scar trees (trees from which bark has been removed to create items like canoes, shelters and containers). It is vital to respect the cultural significance of these areas by adhering to specific guidelines (Figure 2).



FIGURE 2 A cultural significance sign at Uluru

Permission must be obtained before entering heritage sites. Some may have restricted access, for instance, to members of specific First Nations groups. If access is granted, care must be taken not to damage the cultural sites or any artefacts. Furthermore, the significance of these sites should be acknowledged in any reporting or publication of research or experiments conducted at these locations.

2.4 Converting between units

The International System of Units, or SI units, is a standard way of measuring things that is used by scientists around the world.

Measurements must be in the same units before you can compare them. Having the measurements in the same units makes the comparison fair. Figure 3 shows some common standard unit conversions.

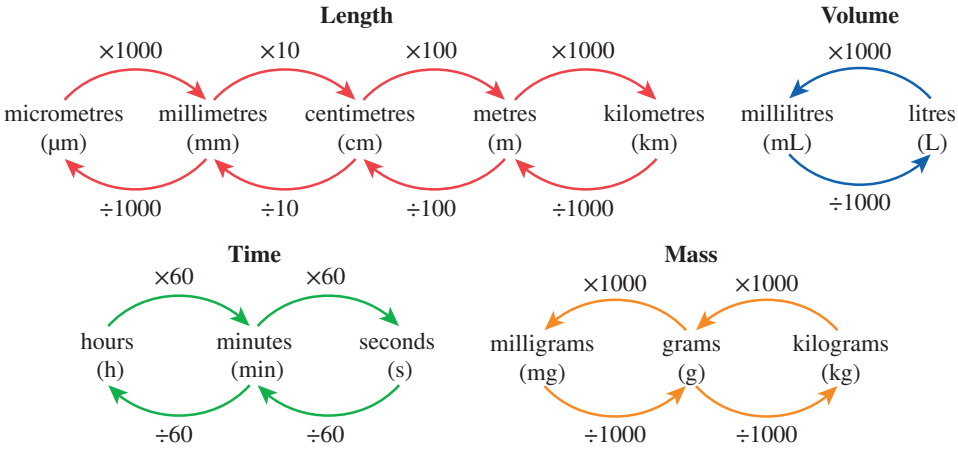


FIGURE 3 Common conversion measurements for length, time, volume and mass

Converting a smaller unit to a larger unit

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

Example

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

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

Converting a larger unit to a smaller unit

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

Example

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

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

Other examples of unit conversions are shown in Table 5.

TABLE 5 More examples of unit conversions

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

Units for time



FIGURE 4 Time recorded on a stopwatch

Time is often measured in minutes (min) and seconds (s). To compare measurements of time or to plot measurements of time on a graph, the times must be converted to just seconds or just minutes. Stopwatches are commonly used in science classrooms to measure time (Figure 4).

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

For example, to convert 5 min and 6 s in Figure 4 to seconds, multiply 5 by 60, giving 300, and then add the 6 s to the total:

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

2.5 Selecting equipment for accurate measurement

The equipment used in science experiments includes items for taking measurements, such as measuring cylinders and stopwatches, and items for specific tasks, such as Bunsen burners and test tubes.

When choosing equipment for taking measurements in science experiments, the type and size of the equipment can affect the accuracy of measurements (Figure 5).



FIGURE 5 Select measuring equipment that will result in the most accurate measurements.

Consider the following when selecting equipment for taking measurements.

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

Example: measuring volume

If you need to accurately measure around 40 mL of a liquid, select a measuring cylinder, as this piece of equipment is designed to measure volume accurately compared to a beaker that only has markings for approximate measurements.

For the greatest accuracy, a 50 mL measuring cylinder (Figure 6) should be used rather than, for example, a 100 mL measuring cylinder. The smaller the measuring cylinder, the smaller the scale **increments** between the **graduations**, which allows for a more accurate reading.



FIGURE 6 A 50 mL measuring cylinder would be the most accurate for measuring 40 mL.

KEY TERMS

increment the value of the difference between graduations on a scale
graduations markings that indicate quantities on a scale

Example: measuring mass

When accurately weighing an object, it is important to use a balance that is accurate enough. Generally, the smaller the quantity the balance can measure, the more accurate the measurement should be. The electronic balance in Figure 7 weighs to two decimal places. Therefore, the increments are 0.01 g for this balance.

When measuring a larger mass, an accuracy of 0.01 g may not be required, so a balance that has increments of 1 g, like the balance in Figure 8, could be sufficient.



FIGURE 7 This digital balance measures mass in grams to two decimal places.



FIGURE 8 This digital balance measures mass in grams to the nearest gram.

Scales and accuracy

The accuracy of measurements such as volume and distance will depend on the scales on the measuring equipment.

Many different scientific instruments use a scale to measure. A scale allows us to compare measurements of different objects. Examples of equipment that use scales are rulers (distance), measuring cylinders (volume) and thermometers (temperature).



FIGURE 10 The increments on this 50 mL measuring cylinder are 1 mL because there are 10 graduations between the 40 mL and the 50 mL marks.



FIGURE 11 The increments on this 10 mL measuring cylinder are 0.2 mL because there are 10 graduations between the 6 mL and the 8 mL marks.

Scales contain labelled graduations, normally spaced an equal distance apart. The difference between one graduation and the next is called an increment, as seen in Figure 9.

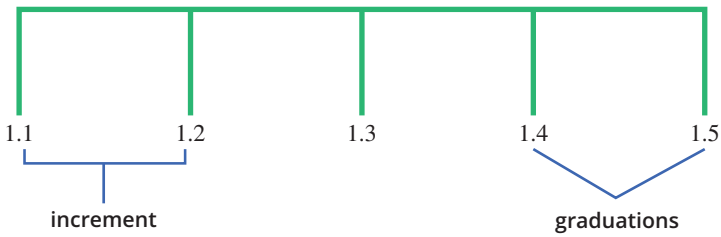


FIGURE 9 Increments and graduations of a scale

The smaller the increment, the more accurate the reading. See Figures 10 and 11 for examples of different increment sizes in measuring cylinders.

2.6 Reducing error and improving accuracy

Errors occur when taking measurements and may be systematic or random errors. Table 6 gives an overview of these types of error.

TABLE 6 Types of experimental error

Error type	Definition	Occurrence	Possible cause
random errors	not the same every time, measured value can be greater or less than the true value	will occur whenever any measurement is taken	using equipment that is not accurate enough
systematic errors	cause a predictable error, measured result is always higher or lower than the true value	do not always occur when taking measurements	an instrument that is not used correctly, such as not being re-zeroed

KEY TERMS

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

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

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

Errors can be reduced in the following ways.

To reduce **random errors** occurring:

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

To reduce **systematic errors** occurring:

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

Example

Mai needs to measure the volume of rainwater that she has collected in a plastic cup. She wants to ensure that her measurement is as accurate as possible. Table 7 shows how she has selected an appropriate piece of equipment to take this measurement.

TABLE 7 Thinking and working used for selection of measuring equipment

Thinking	Working
Mai must select the correct equipment for the task.	Mai knows that the best way to measure volume is using a measuring cylinder. She will use a measuring cylinder to measure the volume of the water she has collected.
How can Mai reduce random error?	Mai knows that the bigger the range of the measuring device, the less accurate it is. Therefore, she needs to choose a measuring cylinder that will have a high level of accuracy for the volume of water she has collected. It shouldn't be too big. She should use a 50 mL measuring cylinder (Figure 12) and read the measurement carefully.
Mai needs to plan to reduce systematic error by thinking about how to use the equipment correctly.	Mai needs to make sure that she is measuring all the water she has collected. If any water is left in the cup, or if any water is spilled when tipping the contents of the cup into the measuring cylinder, her measurement will not be accurate. Mai will carefully tip all the water into the measuring cylinder, making sure all water is successfully transferred. She must also take the reading from the bottom of the curve of the surface of the water (the meniscus), making sure her eyes are level with the surface of the water. This will prevent an inaccurate reading of the volume.
Mai needs to take steps to avoid making mistakes.	Mai will pay close attention to what she is doing and not be distracted. She will double check that she has recorded the measurement correctly, using the correct units.

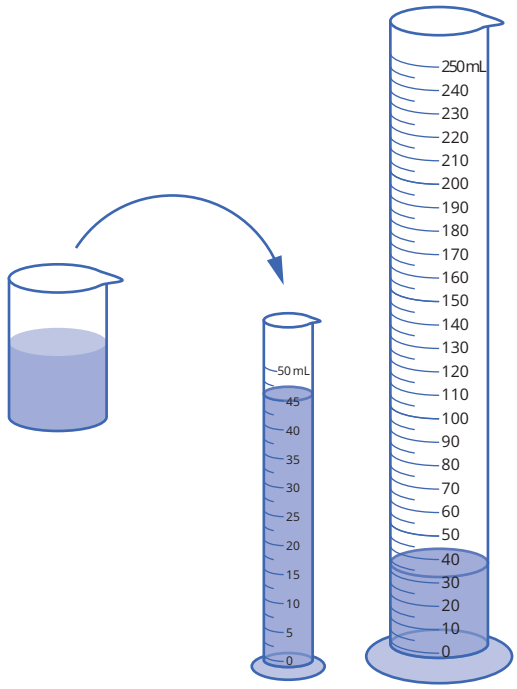


FIGURE 12 Mai should use the smaller 50 mL measuring cylinder on the left.

3 Processing, modelling and analysing

3.1 Identifying cause-and-effect relationships

When one variable is causing changes to another variable, this is a cause-and-effect relationship. Data from an experiment will often find a correlation where there is a link between two variables. However, correlation does not always mean that there is a cause-and-effect relationship (see Toolkit section 1.1).

Proving that the change in the independent variable is causing the change in the dependent variable is more challenging, and requires the application of science knowledge, understanding and the scientific method to the situation.

To establish whether a relationship is cause and effect when undertaking a science inquiry, the following strategies can be used.

- Ensure that the question that is being investigated is a reasonable one and involves variables that can be measured.
- Develop a hypothesis based on scientific understanding.
- Identify all other variables that need to be kept the same (the **controlled variables**).
- Ensure that only the independent variable is changed, and all controlled variables are kept constant (These two points reduce the risk that anything else is causing the dependent variable to change).
- Ensure that there is definite change in the dependent variable by reducing error in the experiment.
- Conduct a control (see next section).

KEY TERMS

controlled variable a variable that is kept constant throughout an experiment

control an experimental trial where the independent variable is not changed

Control

A **control** is an experimental test where the independent variable is not changed. It is often used to compare the results of the independent variable with to see if the independent variable is the cause of the effect.

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

Example

A student is investigating whether there is a cause-and-effect relationship between the amount of stirring and the speed at which sugar dissolves in tap water. Consider the thinking and working steps shown in Table 8.

TABLE 8 Thinking and working involved in testing a cause-and-effect relationship

Thinking	Working
Identify the independent and dependent variable.	Independent variable: Rate of stirring (measured by number of rotations every 10 seconds) Dependent variable: Time taken for sugar to dissolve
Write a hypothesis and/or a prediction based scientific knowledge.	If the rate of stirring increases, the time taken for sugar to dissolve will reduce. (This is based on particle theory and energy of particles.)
Identify all other variables that might affect the rate of dissolving (controlled variables).	temperature of water volume of water size and shape of container type of spoon mass of sugar type of sugar
Carry out the investigation, keeping controlled variables the same throughout.	The investigation was carried out and it was found that as the rate of stirring increased, the time taken for the sugar to dissolve reduced by a few seconds each time the rate of stirring was increased.
Include a control.	A control is carried out where the same rate of stirring was tested four times. It was found that there was a variation of the rate of dissolving by a few seconds even when the rate of stirring was kept the same.
Analyse the data to confirm a correlation.	There seemed to be a correlation between stirring and speed of dissolving because the time reduced as the stirring got faster.
Evaluate the results to confirm a cause-and-effect relationship.	As there was also a change to the speed of dissolving when there was no change to the rate of stirring, it cannot be inferred that this is a cause and effect. There might be something else causing the change to the speed of dissolving.

Often further experiments or an improvement to the experiment method may be required to provide more evidence to test a hypothesis about a cause-and-effect relationship.

3.2 Creating a line graph using a spreadsheet

Graphs are a good visual way to present data. They make data easier to analyse because they will often show trends and patterns. There are many different types of graphs. The following points are useful when creating a graph.

- Line graphs are used to display **quantitative data**.
- The independent variable is placed on the ***x*-axis**.
- The dependent variable is placed on the ***y*-axis**.

KEY TERMS

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

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

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

Using spreadsheets to graph data

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

Spreadsheet programs take data from a table and pres ent it as the type of graph (chart) that you select. You can then add the normal requirements for a line graph, such as axis titles and units for scales, a heading, and a trendline to show the pattern of the data. The spreadsheet program will automatically set the ranges on the scales, but these can be altered if required by selecting the components of the chart.

Entering the data

Step 1: Open a new spreadsheet and enter data into the cells (Figure 13). Place the data for the independent variable in the first column. The spreadsheet program will automatically place this data on the *x*-axis. Place the data for the dependent variable in the second column. This will automatically be placed on the *y*-axis.

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

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

FIGURE 13 The independent variable is the mass of the object and the dependent variable is friction force.

Selecting the graph type

It is important to select the correct graph, or the data may not display correctly.

Step 2: Select the data for the graph by highlighting the two columns (Figure 14).

Step 3: Open the 'Insert' tab.

Step 4: In the Charts group, find Scatter graphs. Choose the Scatter graph without connecting lines. This will generate a graph that you can add a line to.

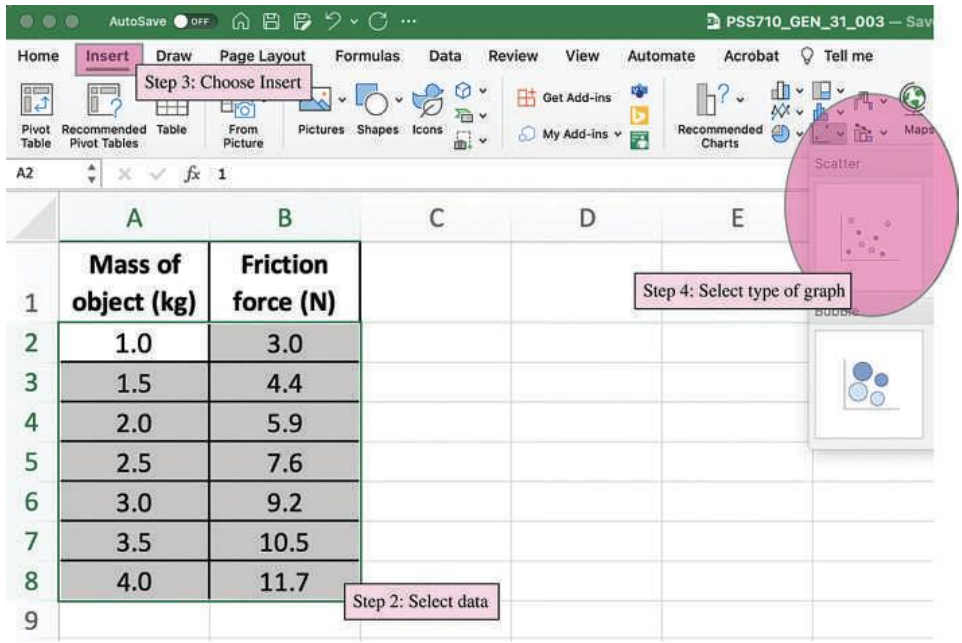


FIGURE 14 Once the data has been selected, you can choose how to present the data.

Completing the graph

Step 5: With the line graph selected, you will see the Chart Design tab. Click on it (Figure 15).

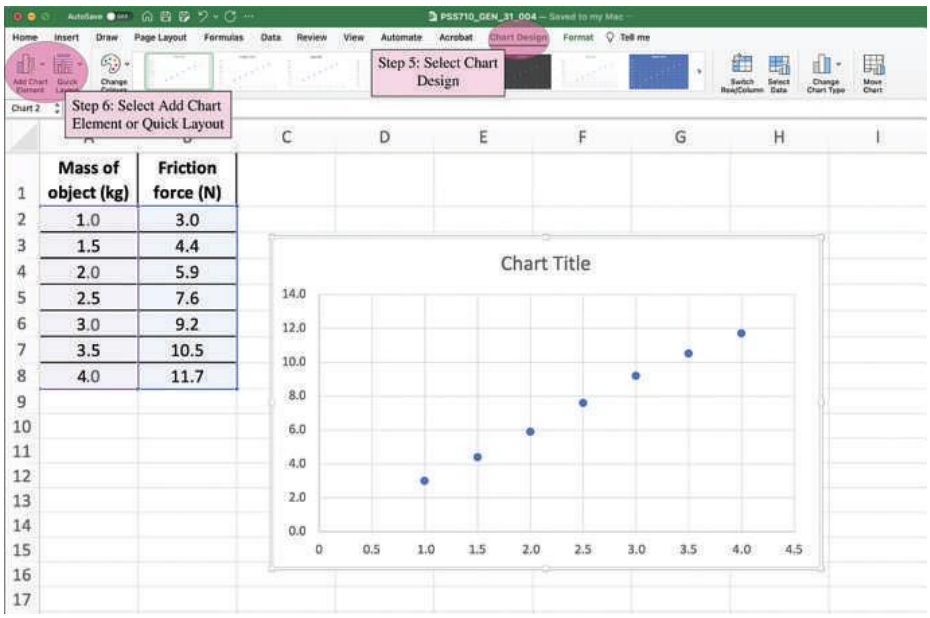


FIGURE 15 You will need to add the correct labels to the graph after creating it.

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

Adding a trendline or joining the points

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

Double click the trendline to open the 'Format Trendline' box. Here, you can change the 'Trendline Options' to find the one that best fits your data (Figure 16).

KEY TERM

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

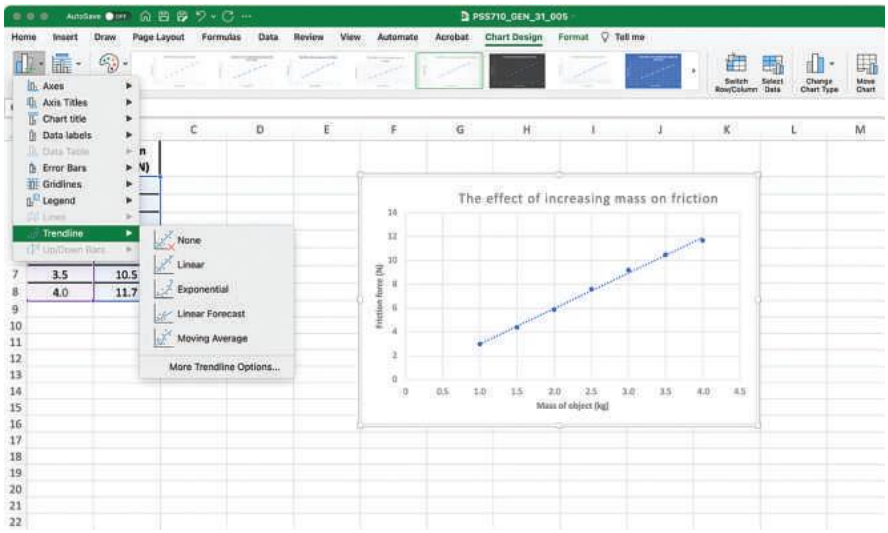


FIGURE 16 How you show the pattern or trend in your data will depend on the data itself.

KEY TERM

discrete data numerical data that can only have certain values

Step 8: If you do not want a trendline and instead want to join the data points with a series of straight lines, double click on one of the data points in the graph. This will open the 'Format Data Series' box. From here, choose the 'Fill and Line' options (the paint can), and select 'Solid line'.

Alternatively, in the Chart Design tab, click 'Change Chart Type' and choose the Scatter graph with straight lines and markers. This type of graph is especially suitable for **discrete data**.

Finalising the graph

Once you have created the graph, you can make changes to improve the clarity of the presentation of data and patterns shown by the data.

Step 9: To change the scale of an axis, click on that part of the graph. This will open the 'Format Axis' box. From here, choose 'Axis Options' (the column chart icon). Under 'Axis Options', you can set the minimum and maximum values for the scale. If you want to change the scale on the other axis as well, click that axis scale and repeat this step.

Step 10: If you want to change any other components of the chart, you can do so by clicking on that component. In this way, you can edit font, colour, size and many other features.

The final graph is shown in Figure 17. In this version, the axis scales have been cropped to fit the data, the colour of the trendline has been changed, secondary gridlines have been added and the label for the *y*-axis has been aligned horizontally for ease of reading.

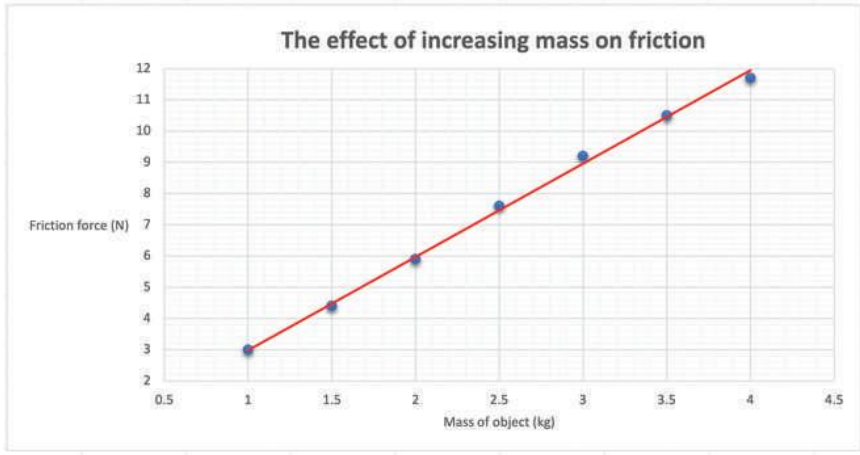


FIGURE 17 The final graph after adjusting the chart elements

3.3 Outliers and anomalies

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

Example

A student was investigating how heart rate changes after exercise. Their results are shown in Table 9.

TABLE 9 Changes in heart rate after exercise

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

This is **continuous data** so it can be displayed as a line graph as shown in Figure 18.

KEY TERM

continuous data numerical data that can have any value

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

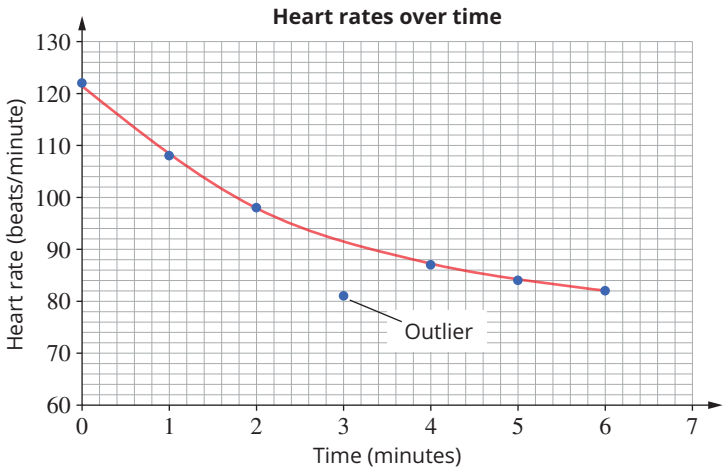


FIGURE 18 Changes in heart rate for 6 minutes after exercise

Managing outliers

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

3.4 Analysing a line graph

Creating a line graph and analysing its shape can help to show the relationship between two variables.

By always placing the independent and dependent variables on the *x*-axis and *y*-axis, respectively, it is possible to use the shape of the line graph to see patterns in the data.

Analysing the gradient

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

Example

Figure 19 shows the change of temperature of water over time as ice is heated.

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

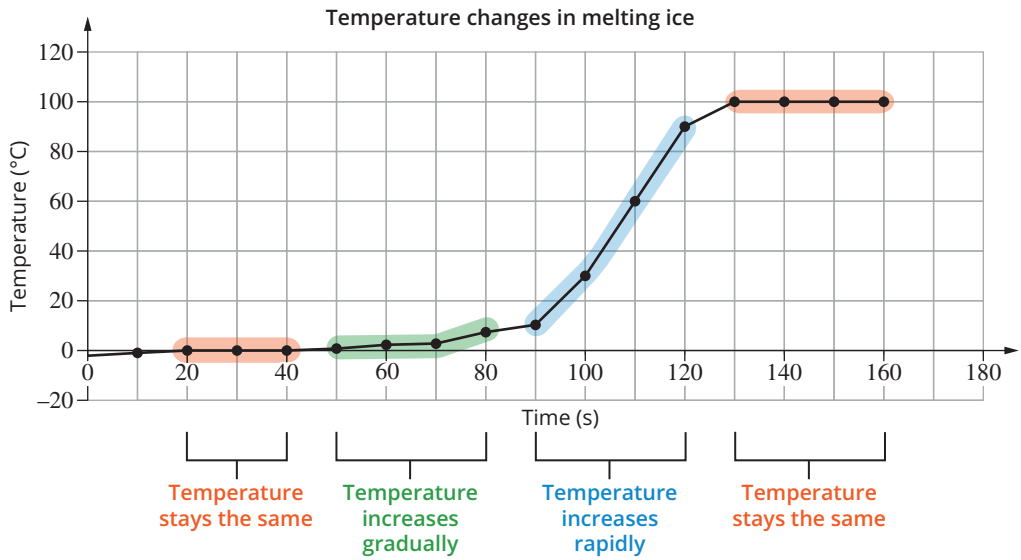


FIGURE 19 A graph showing how the temperature of water changes over time as ice is heated

4 Evaluating

4.1 Evaluating precision

Precision is how well multiple measurements of the same thing, made under similar conditions, give similar results.

Data points are compared to estimate the level of precision. If the values are similar, the precision is likely to be high. The smaller the measurements, the closer the results should be to each other.

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

Example

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

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

The range is calculated as follows:

Range = 912.2 – 911.9 = 0.3 g

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

4.2 Evaluating validity

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

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

KEY TERM

valid a description of an investigation, experiment or method that measures what it set out to measure validity how well an experiment and its results meet the requirements of a fair test

To evaluate the validity of an experiment, it is important to identify all the other variables that might affect the results and to ensure that they are kept constant.

Example

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

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

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

4.3 Evaluating reliability

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

Factors affecting reliability of results

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

Carrying out repeat trials as part of an experiment makes it easier to evaluate reliability. If data from each trial is similar each time, then the method is reliable

Example

The effect of temperature on the melting time for chocolate is being investigated.

In this experiment, the factors affecting the reliability of the results include using the same:

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

The times it takes for 5 g of milk chocolate to melt at 60°C, 70°C and 80°C are measured four times. The results are shown in Table 10.

TABLE 10 The time that 5 g of chocolate takes to melt at different temperatures

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

The results for 60°C and 70°C are reliable, but the results at 80°C are not reliable because they vary considerably from trial to trial.

KEY TERM

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

If a whole experiment is repeated (called a **replicate**) and the overall conclusion is the same, the experiment can be described as reliable (see Toolkit section 2.2 on reproducible experiments).

Note that reliability is not the same as precision. Precision is about just taking a single measurement that is not affected by other variables.

5 Communicating

5.1 Methods for presenting scientific ideas

There are many ways that scientific ideas can be communicated. Table 11 summarises some key points about the various options. You will learn more about some of these at other year levels.

The way that ideas are presented will often depend on the intended audience. You can use this summary to help decide which is the most appropriate method for a specific task.

TABLE 11 Methods for presenting scientific ideas

Method	Description	Notes
written reports	detailed reports that follow a structured format, such as introduction, method, results and conclusion	help in clearly communicating the method and findings from an experiment, enable others to complete the same experiment
posters	should include sections such as the title, introduction, methods, results, and conclusion, and can include graphs and images to make the information accessible	can be an engaging way to present results and ideas, encourage group work and collaboration
presentation	tools such as PowerPoint or Google Slides can be used to create presentations	enable multimedia elements such as videos, images and animations, which can improve understanding and engagement
experiments and demonstrations	live experiments or demonstrations can be carried out in class or as part of a science fair	make ideas more memorable, can include a question and answer (Q&A) component
infographics	can include diagrams, charts and brief text explanations	allow complex ideas to be broken down into visually engaging and easier-to-access sections
scientific journal articles	a report can be in the formal style of a journal article, which can include an abstract (summary), literature review (background from related research), methods and discussion	help students practise formal scientific writing
magazine articles, blogs, or online posts	magazine articles or blogs allow for a more casual approach, including the use of a range of graphics	a scientific approach based on evidence should still be used, allow for questions and further discussion
group discussions and debates	can explain ideas and respond to questions, different people can be assigned specific roles in the discussion	develop critical thinking and communication skills
videos and animations	short educational videos or animations that explain or give examples of scientific concepts	can be effective for explaining processes and systems that are difficult to visualise
podcasts	consist of verbalised text that explains the ideas	content needs to be carefully planned as often will need to explain ideas without the use of graphics for support
models	can be two- or three-dimensional depending on time and resources available, should include labelling and explanation as required	building physical models often improves understanding of scientific concepts around ideas of scale and structure of systems

5.2 Using scientific language

Scientific writing is factual. This means that it provides information or facts that are known to be true. Scientific writing should use scientific language, which can differ from everyday language by:

- being clear. Scientific language uses specific terminology and precise measurements to describe experiments and ideas. For example, a 100 mL measuring cylinder.
- being **objective**. Scientific language should be objective, based on evidence and with no **bias**. For example, using information from reliable sources that have been checked.
- being concise. Complex ideas are broken down into simpler parts, and unnecessary words are avoided. For example, describing the dissolving process by separating what is happening to the solvent from what is happening to the solute.
- using scientific vocabulary. Specialised terms are used to describe ideas and concepts. For example, correctly using terms such as 'hypothesis' and 'variable'.
- using quantities. Data and observations are often described using numbers and measurements where possible. For example, quoting exact quantities, including units, from experiments.

KEY TERMS

objective not influenced by personal feelings or opinions
bias a thought or action that discriminates against, or favours, a particular idea, thing, person or outcome

Example

Table 12 shows two written responses to an investigation of putting two ice cubes into 100 mL of warm water and then putting two ice cubes into 100 mL of cold water. The time taken for the ice cubes to melt was measured.

TABLE 12 A comparison of scientific language

Sample A	Sample B
I thought that when I put ice cubes into warm water, they would melt really quickly and this happened. I'm not sure why it happened but it could have to do with how particles move away from each other. I really enjoyed the investigation, and had really similar results to my friends making it accurate.	It was predicted that when two ice cubes were placed into 100 mL of warm water, they would melt faster than two ice cubes placed into 100 mL of cold water. The cube in warm water melted 305 seconds faster than the cube in cold water. This was due to the increased energy of particles in warm water that was then transferred to the ice cubes, causing them to melt faster.

In Table 12 Sample B uses more scientific language than sample A. It is clearer, uses scientific vocabulary, specific quantities and is objective.

5.3 Using artificial intelligence (AI) in science writing

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

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

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

- not being able to assess the amount of plagiarism in the sources used by the AI to generate responses
- potential errors in the content that the AI was trained on, which can lead to misinformation in the output
- the way the AI works depending on the prompts and the outputs it has been trained on, which can lead to output that 'sounds good' but might be explained in language not suitable for the audience
- random errors creeping into the outputs of AI, such as having the wrong explanation with a particular answer.

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

- ☐ scientific accuracy
- ☐ suitable level for the intended audience
- ☐ correct use of scientific terms and language

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

5.4 Graphic organisers: Venn diagrams

Graphic organisers are charts or diagrams that help organise and present information or ideas. Venn diagrams can be used to compare objects, events or organisms by showing similarities and differences.

Venn diagrams

A Venn diagram makes it easier to compare and contrast the features or characteristics of two items or topics.

- A Venn diagram has two circles that overlap.
- In the centre where the circles overlap, write all the common features/characteristics of the two items or topics.
- In the outer circles, list all the features/characteristics that are different.

An example of a Venn diagram comparing plant and animal cells is shown in Figure 20.

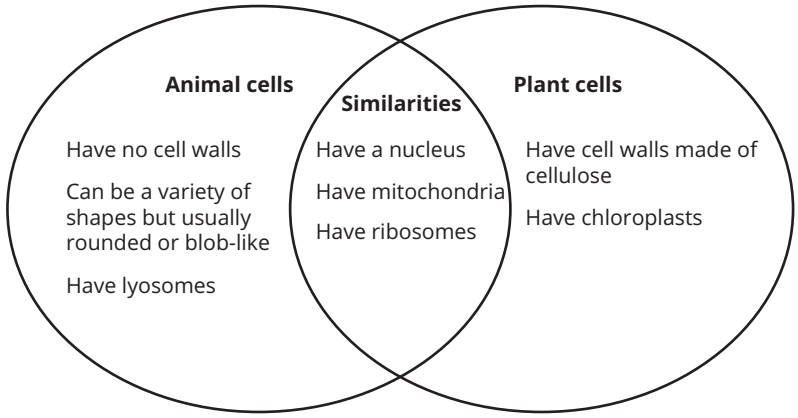


FIGURE 20 A Venn diagram comparing plant and animal cells

Glossary

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

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

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

controlled variable a variable that is kept constant throughout an experiment

control an experimental trial where the independent variable is not changed

continuous data numerical data that can have any value

correlation a relationship or connection between two or more variables

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

discrete data data that can only have separate or specific values

gradient the slope of a line graph

graduations markings that indicate quantities on a scale

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

increment the value of the difference between graduations on a scale

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

objective not influenced by personal feelings or opinions

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

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

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

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

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

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

risk the possibility of something harmful occurring

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

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

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

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

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

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

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



TOPIC 1

Cells in plants and animals

For many thousands of years, humans in Australia and around the world have studied the behaviour of living things from the plant and animal kingdoms: how they moved, found food, and protected themselves from the environment.

It is only since the development of the microscope—less than 500 years ago—that scientists have been able to see living matter at a scale small enough to make a huge discovery.

Living things—from great white sharks to white ants, from blue gum trees in Tasmania to blue *Leschenaultia* plants in Western Australia—are all made up of cells. Some living things are made of just one cell, while other living things are made up of trillions of cells.

It is the features and functions of these cells that support the growth and survival of the living things that the cells create.

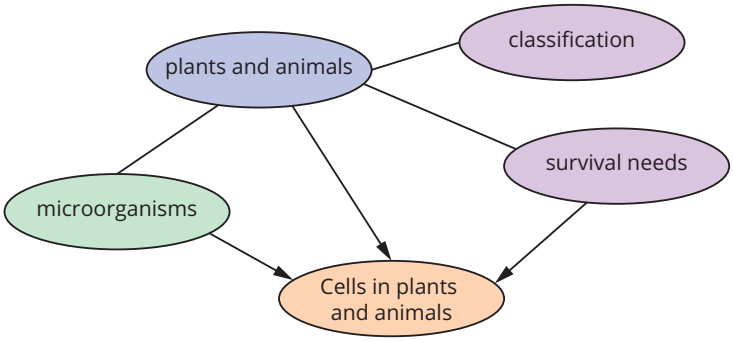
In this topic you will learn about the features and functions of cells.

Learning intentions

- ☐ To understand that cells are the basic unit of living things **3**
- ☐ To understand the features and function of some cells found in the human body **7**
- ☐ To understand how the development of technologies has led to improved understanding of cells **12**
- ☐ To be able to use a microscope to generate data and information **17**
- ☐ To understand the key role of the nucleus in the function of cells **20**
- ☐ To be able to use a microscope to observe and record images of plant cells **22**
- ☐ To understand the roles of the cell wall and cell membrane in the function of cells **25**
- ☐ To be able to investigate the action of a cell membrane **28**
- ☐ To understand the role of the cytoplasm in cellular function **31**
- ☐ To understand the roles of mitochondria and chloroplasts in cellular function **33**
- ☐ To understand the role of vacuoles in cellular function **37**
- ☐ To understand the similarities and differences between animal and plant cells **39**
- ☐ To be able to use microscopes to observe, record and compare unicellular and multicellular organisms **43**
- ☐ To be able to construct and evaluate representations of cells and cell structures **47**
- ☐ To be able to explore the ethical and social implications of scientific discoveries such as stem cells **50**

1 Cells in plants and animals

The key concepts that you will use in this topic:



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

Cells are the basic unit of living things

1 Categorise each of the following as living or non-living.

- **a** dogs
- **b** tables
- **c** people
- **d** bacteria
- **e** grass
- **f** soil
- **g** insects
- **h** viruses

2 What are the characteristics of living things?

3 List the different kingdoms of life.

Types of cells

4 Draw a table to show the differences and similarities between plants and animals.

5 Name two different body systems and briefly explain their function.

6 Explain the benefits of most plants being green in colour.

Observing cells

7 Which of the following would not be able to be seen by the human eye?

- **a** a single bacteria
- **b** a chicken's egg
- **c** a grain of sand
- **d** a mouse
- **e** an atom
- **f** wings of a fly
- **g** apple seeds

1.1 Cells as the building blocks of living things

Lesson overview

Mobile phones are often referred to as cell phones. But why? When mobile phones were first introduced (Figure 1.1.1), their networks were divided into small geographic areas, each with its own network tower to boost signal strength. These areas were called cells, and phones that connected to them became known as cell phones. The networks themselves were often referred to as cellular networks.

In a similar way, cells in biology are the small building blocks that form something much larger and more complex. Every living organism, including humans, is made up of biological cells. If life exists beyond Earth, it is probably built from cells as well.

In this lesson you will learn about how cells are the building blocks of life and how they are part of all living systems.

Learning intention

To understand that cells are the basic unit of living things

Success criteria

SC 1: I can describe cells as microscopic units of living things.

SC 2: I can explain the difference between unicellular and multicellular organisms.

SC 1 I can describe cells as microscopic units of living things

All living things are made up of **cells**. Cells are the smallest living unit and can be thought of as tiny factories that carry out the functions needed for a living thing, or **organism**, to survive. These functions include releasing energy from food, removing waste products and making copies of themselves so that the organism can grow. Figure 1.1.2 shows some stem cells magnified to look much larger than they really are.



FIGURE 1.1.1 An old style 'brick' mobile phone from the 1990s ... not very comfortable to put in your back pocket!

Cell theory

Key ideas about cells were proposed in the mid-nineteenth century, and in 1855 these ideas were brought together to produce what is described as **cell theory**.

- All living things are made up of one or more cells.
- Cells are the basic building blocks of all living things.
- New cells are produced from existing cells.

KEY TERMS

cell the building block of all living things
organism a living thing that functions as an individual
cell theory the idea that all living things are made up of one or more cells that come from pre-existing cells

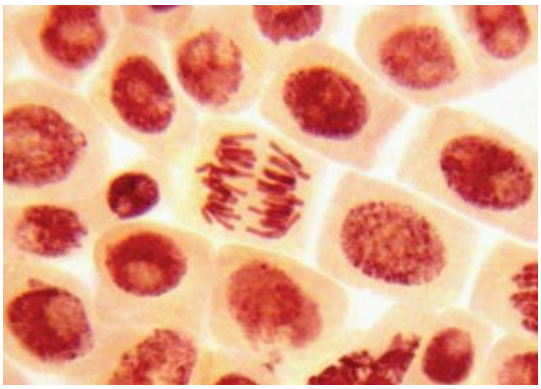


FIGURE 1.1.2 These cells can grow into different types of cells depending on the conditions in the organism; the cell in the middle is in the process of splitting into two cells.

KEY TERMS

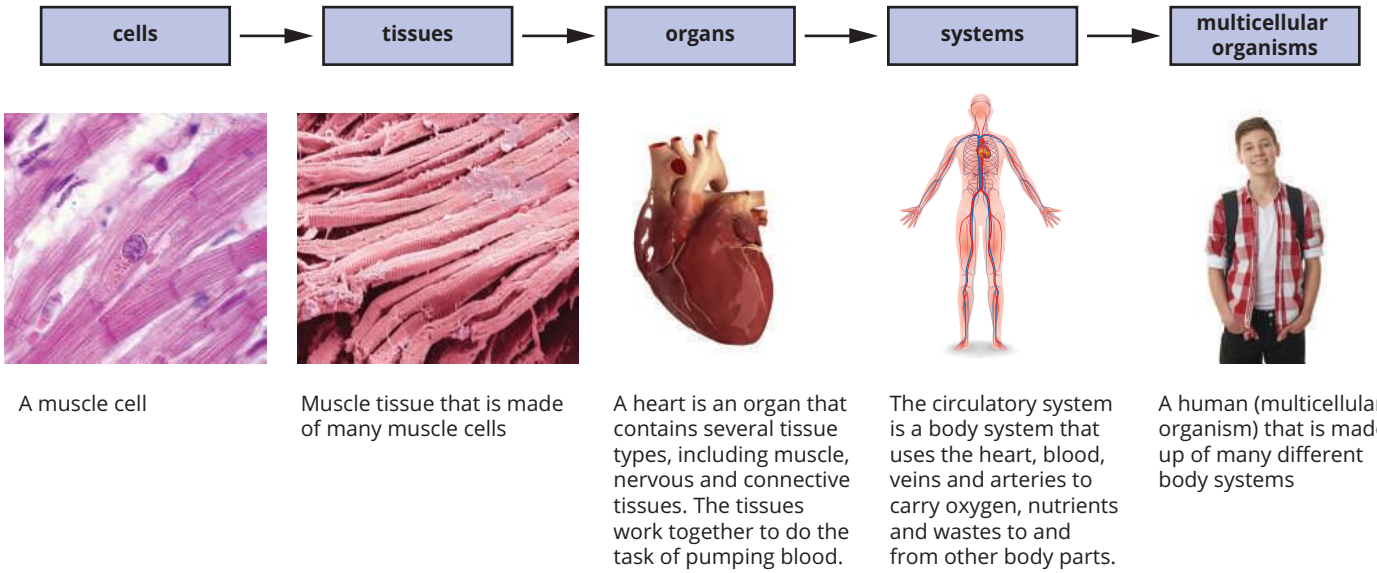
microscope an instrument used to make very small things look bigger
multicellular made up of many cells
body system a group of interconnected organs and tissues that perform functions in the body
organ a structure that contains at least two different types of tissues that work together to complete a function
tissue a group of cells of the same type that carry out the same function in the body

Like most scientific theories, cell theory has evolved as new discoveries have been made. Over time, it has expanded to include additional functions and structures of cells that were unknown a century ago. Modern cell theory now provides greater detail on inheritance, cell composition and energy transfer within cells. Many of these advancements were made possible by improvements in **microscopes**, allowing scientists to observe cellular features with greater precision.

Many organisms are **multicellular**, meaning they are made up of many cells.

Multicellular organisms, such as humans, are highly complex, consisting of interconnected **body systems**. For example, the circulatory system transports essential substances through the blood.

Body systems are composed of **organs**, such as the heart, which in turn are made up of **tissues**, such as muscle. Each tissue is formed by different types of specialised cells suited to its function—for example, muscle tissue consists of muscle cells. This hierarchical organisation of life is shown in Figure 1.1.3.



A muscle cell

Muscle tissue that is made of many muscle cells

A heart is an organ that contains several tissue types, including muscle, nervous and connective tissues. The tissues work together to do the task of pumping blood.

The circulatory system is a body system that uses the heart, blood, veins and arteries to carry oxygen, nutrients and wastes to and from other body parts.

A human (multicellular organism) that is made up of many different body systems

FIGURE 1.1.3 The organisation of multicellular organisms

KEY TERM

organelle a smaller part of a cell in the cytoplasm and having a variety of important functions

What is inside cells?

The shapes you can see inside cells under a microscope are called **organelles**. These are parts of the cell that perform certain roles, such as providing energy and containing the genetic information (DNA) for the organism. You will learn more about organelles later in this topic.

SC 1 CHECK YOUR UNDERSTANDING

List the three components of the cell theory.

SC 2 I can explain the difference between unicellular and multicellular organisms

Number of cells in the human body

Some living things, such as bacteria, are made up of only one cell and are called **unicellular organisms**. If a living thing is made up of two or more cells, it is called multicellular.

KEY TERM
unicellular organism living thing made up of only one cell

Humans are multicellular organisms made up of approximately 30 trillion (30 000 000 000 000) cells.

What cells do

In multicellular organisms, different functions are carried out by different types of cells, or groups of cells working together, in a variety of systems. You can see some examples of these different cell types in Table 1.1.1.

TABLE 1.1.1 Cell types and functions in humans

Cell type	Functions in humans
red blood cells	carry oxygen around the body
muscle cells	provide support and allow movement
egg cells	involved in reproduction
nerve cells (neurons)	carry messages around the body
fat cells	store fat that can be used as energy when the body needs it
stem cells	have the ability to develop into many different cell types

Skin, which is an organ, contains some of these types of cells. Figure 1.1.4 shows the different types of cells in human skin.

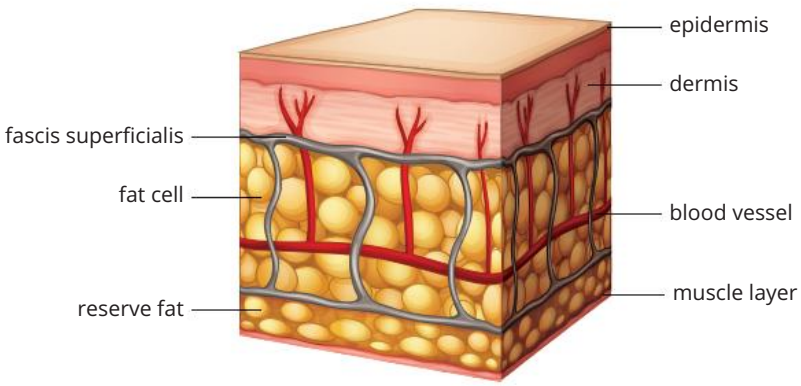


FIGURE 1.1.4 Tissue types in human skin

Scifile

Good bacteria

Probiotic yoghurt is an example of a food that is produced with live bacteria. These bacteria can help your body digest food, reduce the number of disease-causing bacteria, help to create vitamins and help the body to absorb medications.

Unicellular organisms

In unicellular organisms, a single cell carries out all essential functions, including food intake, waste removal, energy production, environmental responses, and reproduction. Bacteria are an example of unicellular organisms. Unlike plants or animals, bacteria belong to the Monera kingdom, which consists of single-celled organisms without a distinct nucleus. They reproduce by creating identical copies of themselves, known as clones.

Some bacteria can cause disease, such as *Staphylococcus aureus* (Figure 1.1.5), which may lead to skin infections and, in rare cases, serious conditions like septicaemia (blood poisoning). These bacteria are commonly known as golden staph.

However, not all bacteria are harmful—many play beneficial roles in human health and the environment.

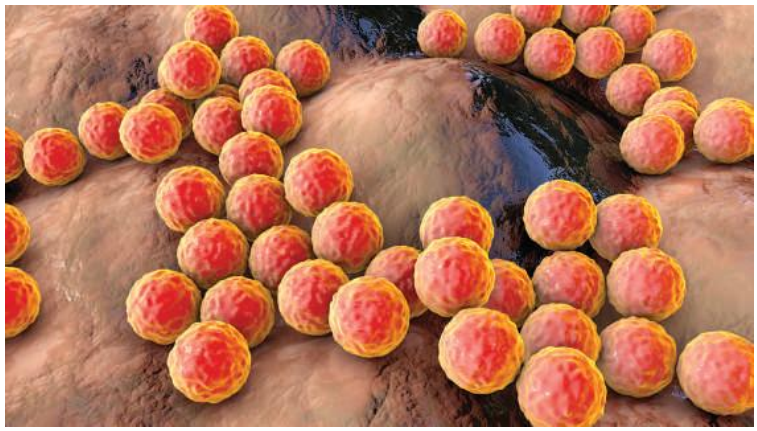


FIGURE 1.1.5 The red spheres are a representation of *Staphylococcus aureus* bacteria, which is a unicellular organism.

SC 2 CHECK YOUR UNDERSTANDING

Name the term that is used to describe organisms that are made up of only one cell and the term for organisms that are made up of many cells.

Lesson review

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

1. List the following terms in order of their biological hierarchy (from least to most complex): human, muscle cells, muscle tissue, circulatory system, heart.
2. Define an 'organ system'.
3. A group of different types of cells was examined under a microscope. They all appeared to be working together. What is the name of the term used to describe what was observed?
4. Classify each of the following as unicellular or multicellular.
   a. bird
   b. bacteria
   c. tree
   d. mammal
5. Ralph took a sample of water from a local creek, and then observed the water under a microscope. He noticed that there were many small simple organisms vibrating around. Is it more likely that Ralph observed multicellular or unicellular organisms? Explain your choice.

1.2 Cells in humans

Lesson overview

All humans start from an egg cell that has been fertilised by a sperm cell.

A fertilised cell contains the genetic information required to create all the cells that make up an average human.

Most of these cells have specific functions in the body. These include protection from disease, transporting oxygen to muscles and making up muscles used for movement and support.

In this lesson you will learn about the different types of cells in your body, their relative sizes and what some of these cells have in common.

SC 1 I can state the function of different types of cells in humans

The human body contains a wide variety of **specialised cells**, each with a unique structure that enables it to perform a specific function. These cells work together within tissues and body systems to sustain life.

Some essential processes, such as **cellular respiration**, occur within individual cells, while others involve interactions between cells. For example, in the nervous system—which transmits and processes signals to coordinate movement and sensory information—messages travel from one cell to another. Other functions involve the movement of materials, such as red blood cells transporting oxygen throughout the body.

Despite their differences in structure and function, all cells contain the same genetic material (**DNA**), which is unique to each individual. Examples of specialized cells can be seen in Figure 1.2.1 and Table 1.2.1.

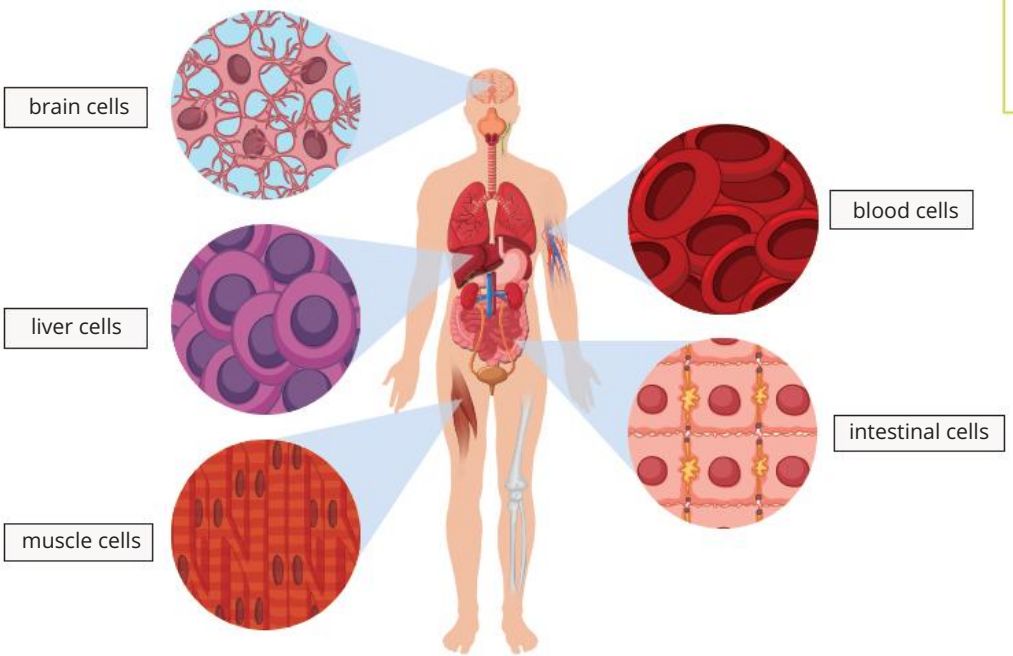


FIGURE 1.2.1 A human has many different types of cells that have different features and functions.

Learning intention

To understand the features and function of some cells found in the human body

Success criteria

SC 1: I can state the function of different types of cells in humans.

SC 2: I can compare the scale of different types of cells in humans.

SC 3: I can describe some features that are common to most types of cells.

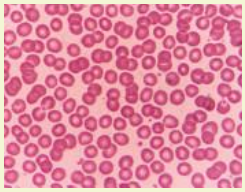
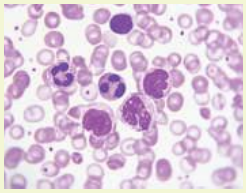
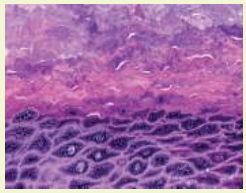
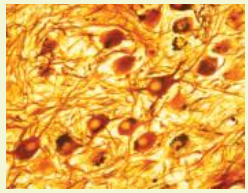
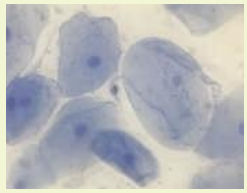
KEY TERMS

specialised cell a cell that has specific structures to allow it to perform specific functions

cellular respiration a set of processes in the cells that converts chemical energy from nutrients into energy (ATP) that can be used by cells

DNA deoxyribonucleic acid, the molecule that contains genetic information for an organism

TABLE 1.2.1 Examples of specialised cells in the body viewed under a microscope

Red blood cells are small flexible cells that transport oxygen around the body.	**White blood cells** stop foreign organisms such as bacteria and viruses from causing infections in the body. The picture below shows six white blood cells (larger cells) among red blood cells.	**Skin cells** create a tight barrier against microorganisms and environmental factors such as bacteria, viruses, UV light, heat and cold. The picture below shows the cross-section of skin cells (stained purple).	**Nerve cells** have long extensions to relay information and send commands to other cells, muscles and organs.	**Cheek cells** produce mucus to help to start the digestion process and protect from bacterial infection. The picture below shows stained cheek cells.
				

When cells do not function properly

Many common diseases are caused by a lack of healthy cells that can carry out their functions properly. Table 1.2.2 summarises some medical conditions related to poor cell health. Some of these diseases are potentially fatal (cause death).

TABLE 1.2.2 Some common cell health issues and the diseases they can cause

Cell health issue	Disease	Effects
lack of healthy red blood cells	anaemia	fatigue, pale skin, shortness of breath
body's immune system cannot tell the difference between the cells of the body and foreign cells	autoimmune diseases	different diseases will have different effects, including arthritis that causes joint pain
cells that reproduce uncontrollably	cancer	organs and tissues may not function correctly
low white blood cell count	leukopenia	reduced ability to fight common infections

SC 1 CHECK YOUR UNDERSTANDING

Specialised cells can carry out specific functions. List two types of specialised cells and explain their function in the body.

SC 2 I can compare the scale of different types of cells in humans

Size of cells in the human body

The human eye can only see objects that are bigger than approximately 0.1 mm without any magnification. To see objects that are smaller than this, you will need a magnifying instrument such as a microscope. Objects that can be seen without microscopes can be described as **macroscopic**. Macroscopic objects are usually larger than 1 mm (1000 μm). Objects that can only be seen using a microscope are described as **microscopic**.

Because cells are so small, their size is measured using a unit called a **micrometre** (μm). A micrometre is one-thousandth of a millimetre. A comparison of units of length is shown in Table 1.2.3.

KEY TERMS

macroscopic can be seen without the help of a microscope
microscopic can be seen only by using a microscope
micrometre one-thousandth of a millimetre, or one-millionth of a metre; the standard unit for micrometre is μm

TABLE 1.2.3 Micrometres compared to larger units

Unit	Number of micrometres (μm)
1 metre (m)	1 000 000
1 centimetre (cm)	10 000
1 millimetre (mm)	1000

SCIENCE IN SOCIETY

Unlocking the hidden complexity of the cell

Since the invention of the microscope by Dutch spectacle maker Zacharias Janssen, and the first observation of cells by Antonie van Leeuwenhoek, scientists have continuously improved and refined technology to uncover new and intricate features within cells.

Although the first cells observed revealed only the basic outline of a cell, microscopes became increasingly sophisticated, enabling scientists to observe even the smallest cells and uncover their internal components. Modern electron microscopes now provide detailed views of internal structures, including those within mitochondria (Figure 1.2.2).

Recent research suggests that cells contain more than 30 distinct organelles, known as biomolecular condensates, each with specialised functions. Ongoing studies will further clarify their roles, deepening the understanding of cellular complexity.

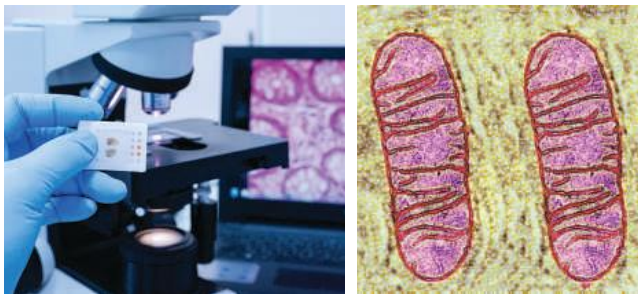


FIGURE 1.2.2 Microscopes (left) allow scientists to see small details that the human eye cannot, such as mitochondrion structure within a cell (right).

Most human cells are between 8 and 60 µm, but some cells in the body are a lot longer than this, depending on their function.

Human cells are a lot bigger than most bacteria, which are between 0.1 and 1.5 µm. Table 1.2.4 gives the sizes of some cells in the human body, and Figure 1.2.3 compares the sizes of some human cells with some other organisms.

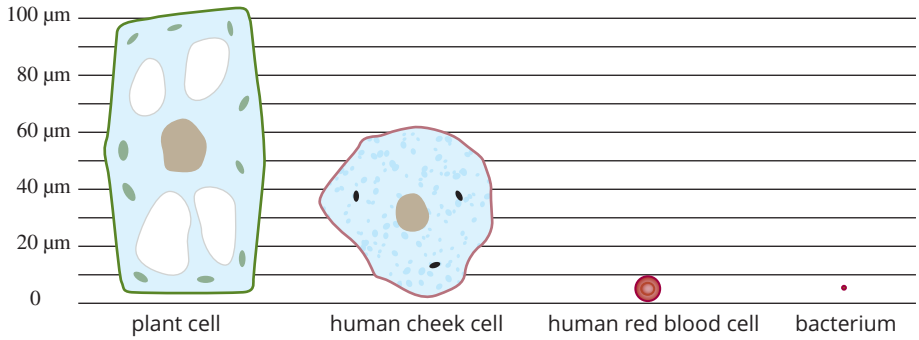


FIGURE 1.2.3 The relative sizes of some human cells (cheek and red blood cell), a plant cell (larger) and a bacterium (smaller)

TABLE 1.2.4 Approximate sizes of cells in the human body

Type of cell	Approximate size of cells
red blood cells	5–8 µm
white blood cells	6–14 µm
egg	100 µm
cheek cells	50–100 µm
sperm	length 4.5 µm, width 2.8 µm
cardiac muscle cells (in the heart)	length 100 µm, width 20 µm
skeletal muscle cells (connected to bones)	length up to 5 cm, width 100 µm
nerve cells	length 100 µm up to 1 m

SC 2 CHECK YOUR UNDERSTANDING

Micrometres are very small, and some objects are invisible to the naked eye.

a What must be used to view objects that are less than 100 µm in size?

b State the term used for objects that are larger than 1000 µm in size.

GO TO
Toolkit section 2.4, Converting between units

SC 3 I can describe some features that are common to most types of cells

Although humans are made up of many different types of cells, most human cells have the same features and organelles (specialised structures).

- **Cell membrane**: the 'skin' around the cell that holds the cell together and controls what goes in and out of the cell.
- **Ribosome**: an organelle that makes proteins that are used by the cell for growth and repair.
- **Nucleus**: the organelle that contains the genetic instructions (DNA) for the cell's functions.
- **Mitochondrion**: the organelle where most of the energy needed to power the cell's chemical reactions is generated by a process called cellular respiration.
- **Cytoplasm**: a jelly-like fluid that contains all cell components, except the nucleus.

You can see these features of a cell in Figure 1.2.4.

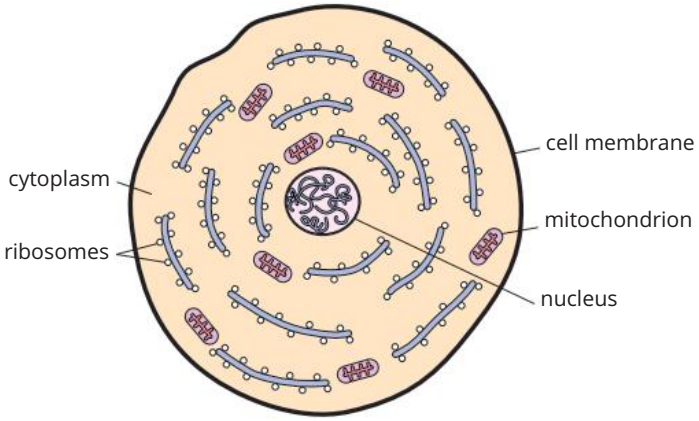


FIGURE 1.2.4 Cross-section diagram showing the basic features of a typical animal cell

SC 3 CHECK YOUR UNDERSTANDING

The nucleus is often described as the 'control centre' of the cell. Explain why people might refer to it as this.

Lesson review

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

1. All cells contain common features. List the features that are common to most types of cells in your body.
2. Different cells have different functions. Name the type of cell that is responsible for:
   a. transporting oxygen around the body
   b. sending messages around the body that allow it to move
   c. protecting the body against infection.
3. Explain what the cell membrane is useful for.
4. Muscle cells contain many mitochondria, a lot more than some other types of cells. How would this be useful to the body?
5. List the following measurements in order from smallest to largest:

   1.8 cm, 25 mm, 30 000 µm, 1 cm, 80 mm, 20 µm
6. A student examined eight cells lined up in a row under a microscope. The total length was 480 µm. Using Table 1.2.4, state the type of cell this would most likely be and explain your choice.

1.3 The development of microscopes

Learning intention

To understand how the development of technologies has led to improved understanding of cells

Success criteria

SC 1: I can outline the key developments in microscope technology from the first microscope to present day.

SC 2: I can outline the key discoveries about cells from Hooke's first description of cells to present day.

SC 3: I can describe how specific improvements in microscope technologies lead to new discoveries about the structure and function of cells.

KEY TERM

lens a piece of glass or other transparent material with curved sides used in optical equipment

Lesson overview



FIGURE 1.3.1 Zacharias Janssen and his father

Zacharias Janssen (Figure 1.3.1), the son of a Dutch spectacle maker, is believed to have invented the first microscope around 1590 by placing two lenses inside a tube. This marked the creation of the world's first true microscope, opening the door to the discovery of previously unseen microscopic life.

Since then, scientists have continually improved microscope designs. In modern times, the use of electron beams has allowed for imaging of structures even smaller than what visible light can reveal. Today's electron microscopes can magnify objects up to 1 million times their actual size, providing unprecedented detail.

Advancements in microscope technology have enabled scientists to explore cells with greater clarity and depth, leading to groundbreaking discoveries about their structure and function.

SC 1 I can outline the key developments in microscope technology from the first microscope to present day

The discovery of cells

In 1665, English scientist Robert Hooke used a microscope with a simple **lens**—like the one shown in Figure 1.3.2—to investigate cork. He saw that the thin slices of cork (Figure 1.3.3) resembled honeycomb because of the little boxes, or cells, they were made up of. You can see them in his drawing. Hooke had discovered the building blocks of life: cells.



FIGURE 1.3.2 Robert Hooke's microscope

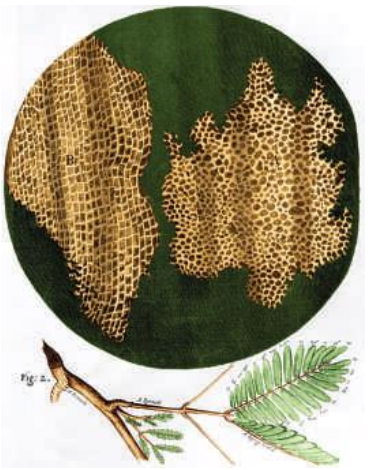


FIGURE 1.3.3 Hooke's drawing of cork cells; these are dead plant cells with only the cell walls remaining.

Microscope development

The timeline in Figure 1.3.4 outlines the key developments in microscope technology and the scientists who were involved in these developments.

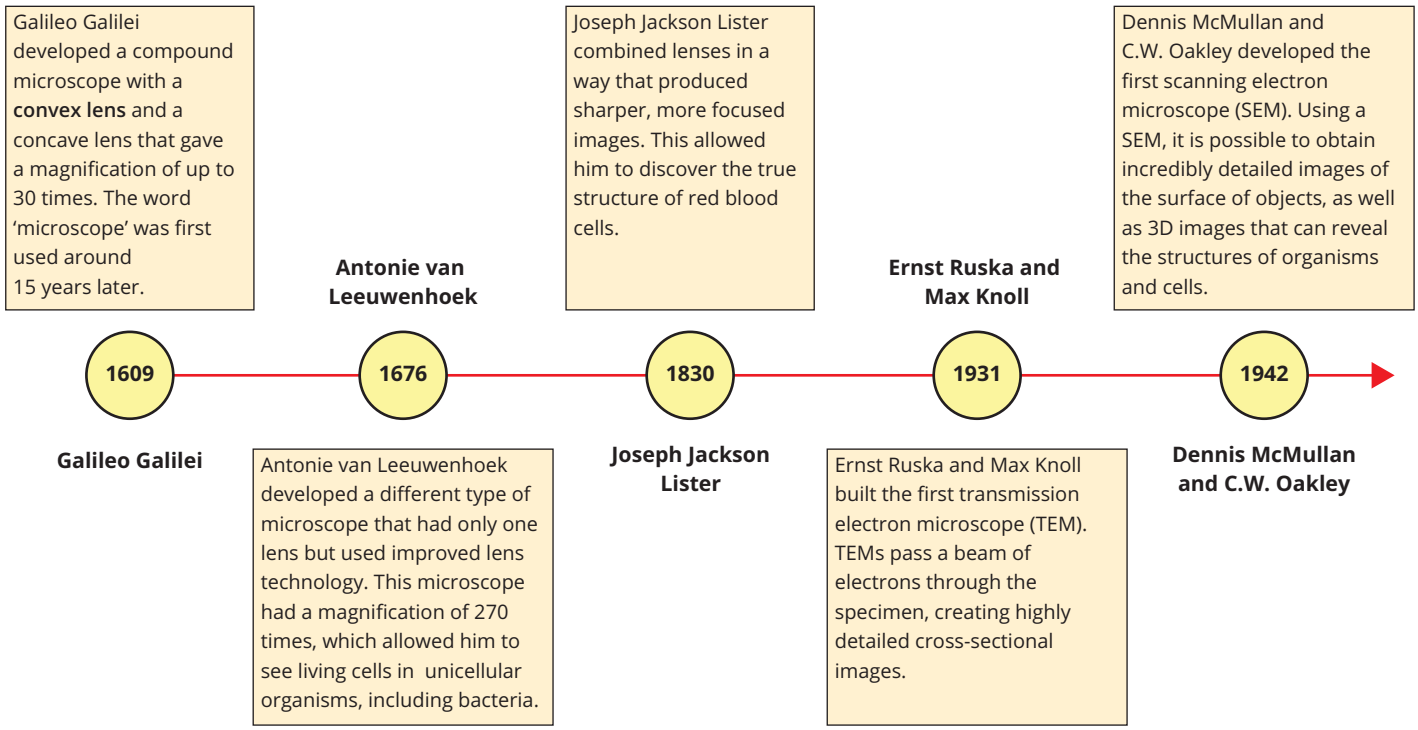


FIGURE 1.3.4 Key developments in microscope technology from the first microscope to present day

SC 1 CHECK YOUR UNDERSTANDING

Describe the first type of microscopes that were used to magnify objects.

KEY TERM

convex lens a lens that has at least one surface curving outwards

SC 2 I can outline the key discoveries about cells from Hooke's first description of cells to present day

The timeline in Figure 1.3.5 is a summary of the key discoveries about cells from Hooke's first description of cells to the present day.

The timeline is a summary, and in many cases other scientists were involved in the various discoveries. The discovery dates are also approximate, because when a scientific discovery is made, it needs to be accepted by a wider scientific community before being accepted. This process could take an especially long time in the nineteenth century when communication between scientists was more difficult than it is today. Even now, with today's communication technologies and global networks of scientists, it takes time to have a scientific discovery accepted.

1665, England	**Cells and cell walls**	Robert Hooke observes cells and cell walls. He uses the word 'cell' to describe microscopic honeycomb cavities in cork.
1670s, The Netherlands	**Single celled organisms**	Antonie van Leeuwenhoek observes single-celled organisms, such as protozoa, while using a microscope to examine pond water.
1833, Scotland, England	**Nucleus**	Robert Brown becomes the first person to name and describe the cell nucleus in detail.
1855, Switzerland and Germany	**Cell membrane**	Carl von Naegeli and Karl Cramer discover the cell membrane.
1863, Switzerland	**Cytoplasm**	Rudolf Albert von Kolliker gives the name 'cytoplasm' to all the material within a cell.
1890, Germany	**Mitochondria**	Richard Altmann describes mitochondria as elementary living units.
1952, Romania and the United States	**Mitochondria (finer detail)**	George Palade publishes a study on the fine structure of mitochondria.
1955, Romania and the United States	**Ribosome**	George Palade discovers ribosomes using an electron microscope.



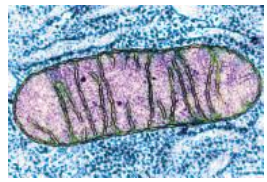


FIGURE 1.3.5 Timeline of key discoveries about cells

SC 2 CHECK YOUR UNDERSTANDING

Describe the types of cells that Antonie van Leeuwenhoek observed in pond water.

SC 3 I can describe how specific improvements in microscope technologies lead to new discoveries about the structure and function of cells

Light microscope

Light microscopes (sometimes called optical microscopes) use a combination of lenses to produce a magnified image of a specimen (the object being observed).

Compound microscope

Microscopes that have more than one lens are called compound microscopes (Figure 1.3.6). The specimen is lit from below using a lamp or a mirror, so the specimen must be very thin to allow the light to pass through to the observer.



FIGURE 1.3.6 A compound microscope with one eyepiece (monocular)

Stereo microscope

A **stereo microscope** has two eyepieces and two objective lenses. This means the image is viewed through two combinations of lenses that focus on the same point but from different angles, which produces a three-dimensional image. The specimen in a stereo microscope is lit from above (or the side). Because light does not have to pass through the specimen, the specimen can be almost anything, unlike for a light microscope. Stereo microscopes are used to examine and dissect animal and plant specimens, as shown in Figure 1.3.7.



FIGURE 1.3.7 A researcher using a stereo microscope to help dissect a plant

Electron microscope

Electron microscopes use beams of tiny particles called electrons to create an image of the specimen. They can magnify up to a million times. Electron microscopes produce black-and-white images, but these are often coloured later to highlight important features. There are many types of electron microscopes, including transmission electron microscopes (TEMs), like the one in Figure 1.3.8.



FIGURE 1.3.8 A transmission electron microscope (TEM) and the technology required to view the images

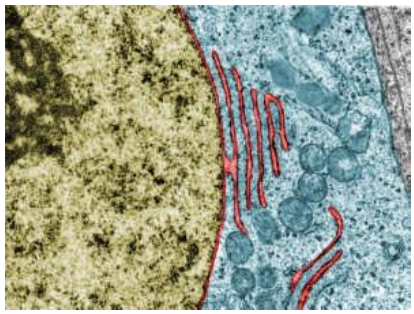


FIGURE 1.3.9 A TEM micrograph showing the boundary between the nucleus on the left (coloured gold) and the cytoplasm (coloured blue)

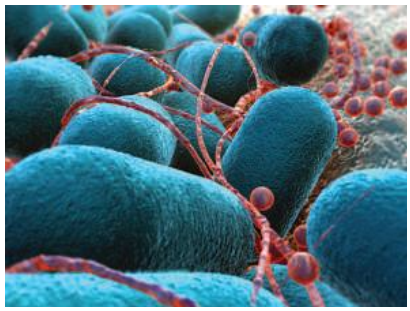


FIGURE 1.3.10 A SEM micrograph showing unicellular rod-shaped *E. coli* bacteria (coloured blue)

KEY TERM

micrograph a photograph of an image from a microscope

Transmission electron microscope (TEM)

In TEMs, electrons pass through the specimen, so the specimen needs to be sliced into incredibly thin sections. TEMs make it possible to view the structures of cells. Figure 1.3.9 shows some structures inside a cell. The colours have been added to help each part stand out.

Scanning electron microscope (SEM)

In SEMs, the image is formed by electrons reflecting off the surface of the specimen. SEMs are used to provide three-dimensional images like the one in Figure 1.3.10.

Scanning tunnelling microscope (STM)

Scanning tunnelling microscopes (STMs) were first used in the 1980s and are incredibly powerful. They can create images of individual atoms and molecules. STMs are used for investigating non-living materials such as the surface of metals and crystals.

Photomicrography

Photomicrography involves taking a photograph through a microscope to capture the image of the specimen. Photomicrography can be used in both optical and electron microscopes and is used in a range of fields of science, including medicine, geology, forensics and cell biology. It is also an artform that can be used to engage people in the microscopic world. The term **micrograph** is commonly used to describe these pictures taken.

SC 3 CHECK YOUR UNDERSTANDING

Describe what type of image is observed with a stereo microscope.

Lesson review

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

1. State the name given to a photograph that is produced from an object observed under a microscope.
2. Name the microscope that can be used to see fine structures within the mitochondria.
3. Name the microscope that would be most appropriate to use in a classroom for viewing cells in pond water. Explain your choice.
4. Describe how photomicrography would be useful to scientists conducting research.
5. If Galileo Galilei used his microscope to examine some 0.1 mm long plant cells, how big would they appear?

1.4 Using a microscope

Introduction

Microscopes have been essential in the discovery of cells, the development of cell theory, and the advancement of cellular biology. While there are many types of microscopes, they all serve the same fundamental purpose: allowing scientists to observe details beyond the limits of the naked eye.

Even the simple microscopes used in school laboratories provide valuable insights, such as revealing cell structures that would otherwise remain unseen.

In this practical investigation, you will learn how to use a light microscope and how to calculate the magnification of a microscope when viewing specimens.

Background

The type of microscope used in schools and many science laboratories is a light microscope. You will probably use a microscope like the one shown in Figure 1.4.1. A light microscope with one **eyepiece** (or ocular lens) is called a monocular microscope, and one with two eyepieces is called a binocular microscope. The parts of a light microscope can be seen in Figure 1.4.1.

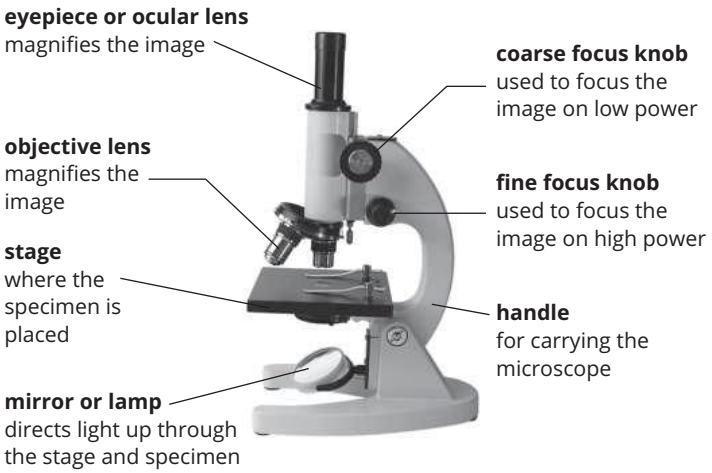


FIGURE 1.4.1 The key parts of a compound microscope and their functions

Microscope magnification

The light microscope uses light and a system of lenses to magnify the image. One lens is called the eyepiece (or ocular lens). This is the lens closest to your eye. The other lens is the **objective lens**. It is closer to the specimen. Microscopes that have two lenses are called compound microscopes.

The **magnification** of the microscope tells you how much bigger the image is than the real object. If the microscope has a magnification of 10×, then the image is 10 times bigger than the actual object.

The **field of view** refers to how much of a specimen is visible when looking through a microscope (Figure 1.4.2). As magnification increases, a smaller portion of the specimen is seen, reducing the overall field of view. This means that zooming in on a specific area provides more detail but reveals less of the whole object.

Learning intention

To be able to use a microscope to generate data and information

Success criteria

SC 1: I can identify key parts of a light microscope and describe their functions.

SC 2: I can calculate the total magnification of a light microscope.

SC 3: I can safely use a microscope to observe and record observations of specimens at a range of magnifications.

KEY TERMS

eyepiece the lens, or combination of lenses, at the viewing end of a microscope or telescope
objective lens the lens in a microscope or telescope that is nearest to the object being viewed
magnification the ratio of the size of an image to the size of the object
field of view the amount of the specimen seen through a microscope



FIGURE 1.4.2 The field of view under a microscope showing bacteria

The maximum magnification of a light compound microscope is about 1000 times bigger than the specimen when seen with the naked eye. At this magnification, some of the largest bacteria are just visible. The maximum magnification of stereo microscopes is about 100×.

SkillBuilder

Calculating the magnification of a microscope

Most microscopes used in school have two lenses: the eyepiece (or ocular lens) and the objective lens. Both lenses magnify the specimen. The total magnification of the microscope is the combined effect of the two lenses.

To calculate the total magnification, you multiply the magnification of the eyepiece by the magnification of the objective lens.

total magnification = eyepiece magnification × objective lens magnification

Important information

The eyepiece and the objective lenses are labelled with their magnification.

The eyepiece magnification on a microscope is fixed, but there are different objective lenses that range from 4× to 100× that can be changed by rotating the nose piece.

Example

Stephanie was using a microscope with an eyepiece with a magnification of 10×; an objective lens of 4× was also in place. To calculate the total magnification, she multiplied the magnification of the eyepiece by the magnification of the objective lens.

total magnification = eyepiece magnification × objective lens magnification

total magnification = 10 × 4 = 40

The correct way to write the magnification is with a multiplication symbol after the number, so Stephanie's microscope had a magnification of 40×.

Aim

To become familiar with the workings of a microscope by observing common objects at various magnifications

Materials

- small samples suitable for viewing under a microscope, such as sugar crystal (both plain and caster), salt, copper sulfate crystal, strand of hair, clothing fibres, small section of a leaf, writing sample, small newsprint
- light microscope
- microscope lamp (if the microscope does not have an inbuilt light source)
- glass microscope slides
- tweezers

Assessment of risk

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

SAFETY NOTE

- Ensure that you follow the correct way to focus the microscope so that you do not damage the specimen or the objective lens.

GO TO
Toolkit section 2.1, Reducing risk

Method

1. Place the sample carefully in the middle of a microscope slide. Place the microscope slide on the stage, holding it in position using the clips.
2. Adjust the mirror and/or light source so that the maximum amount of light is passing through the slide.
3. Select the objective lens with the lowest magnification.
4. Looking at the microscope from its side, adjust the coarse focusing knob to bring the stage and objective lens as close as possible to each other without touching.
5. Looking through the eyepiece, turn the coarse focusing knob so that the stage and objective lens move further apart.
6. Repeat steps 4 and 5 until the specimen is in focus.
7. If you miss the point of focus, go back to step 4 and start again.
8. Use this procedure to observe each specimen using the microscope.

Results

Draw a table in your notebook, like the one below. In the table, sketch a diagram of your observations for each specimen. Record the magnification used to obtain the clearest image of the object and describe any observations that would not have been possible without the microscope.

Specimen		**Sketch**
Magnification		
Microscopic observations		

Evaluation

1. List three parts of the light microscope and briefly explain their function.
2. Outline how the magnification of a lens affects the field of view in a light microscope.
3. Explain why it is important to know the total magnification when using a microscope.
4. What is multiplied when calculating the magnification of a specimen viewed under a light microscope?
5. Compare the total magnification when using a 10× eyepiece with a 4× objective lens versus a 40× objective lens.
6. Outline how you would record your observations when viewing a specimen under different magnifications.

1.5 The functions of the nucleus in cells

Learning intention

To understand the key role of the nucleus in the function of cells

Success criteria

SC 1: I can identify the nucleus from a visual representation of a cell.

SC 2: I can explain the function of the nucleus of a cell.

KEY TERMS

eukaryotic cell a cell that has a nucleus
nucleolus an organelle within a cell nucleus that produces ribosomes
prokaryotic cell a cell that does not have a nucleus
cytoplasm everything contained within a cell membrane except the nucleus

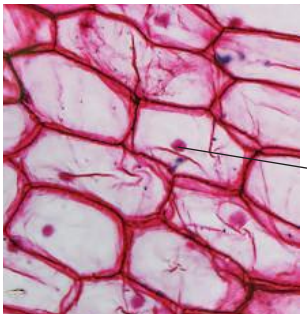


FIGURE 1.5.2 Stained cells showing the nucleus in the central location

Lesson overview

The nucleus of a cell can be described as the information centre for the cell. The nucleus contains all the genetic information required for that cell, and almost every other cell in the organism contains this same genetic information. This genetic information is vital for the survival of the cell and the organism that the cell belongs to.

Figure 1.5.1 shows the nucleus of an animal cell surrounded by the other components of the cell.

In this lesson you will learn how to identify the nucleus of a cell and what its key functions are.

SC 1 I can identify the nucleus from a visual representation of a cell

The first organelle to be identified within a cell was the nucleus. Both plant and animal cells contain a nucleus, like the ones in Figure 1.5.2 where the nuclei (the plural of nucleus) look like dots in the middle of the cells.

Cells that contain a nucleus are called **eukaryotic cells**.

The nucleus is normally drawn as a circular or oval shape in the centre of a cell diagram. Sometimes a smaller circle can be seen within the nucleus. This structure is called the **nucleolus** (Figure 1.5.1).

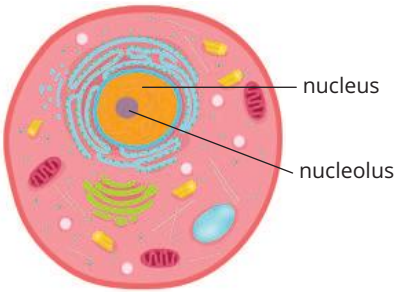


FIGURE 1.5.1 A diagram of an animal cell containing a nucleus

Ribosomes, which are involved in the production of proteins, are produced in the nucleolus of eukaryotic cells.

Some cells in unicellular organisms, such as bacteria, do not a contain a nucleus. These are called **prokaryotic cells**. However, they still contain DNA, which is spread out in the **cytoplasm** of the cell.

SC 1 CHECK YOUR UNDERSTANDING

Describe the location of the nucleus in a eukaryotic cell.

SC 2 I can explain the function of the nucleus of a cell

The nucleus can be considered the control centre of the cell. It is called this because it contains genetic material (in the form of DNA), which provides the instructions for the cell, including for the chemical reactions in the cell, how the cell develops and how it reproduces.

Every nucleus in every cell of an organism, whatever the function of the cell, contains the same DNA. The nucleus is surrounded by a membrane that protects the nucleus and the DNA inside it. The DNA of animal and plant cells is so long that it needs to be tightly packaged into chromosomes so that it fits inside the nucleus (Figure 1.5.3). DNA is made up of small sections called genes.

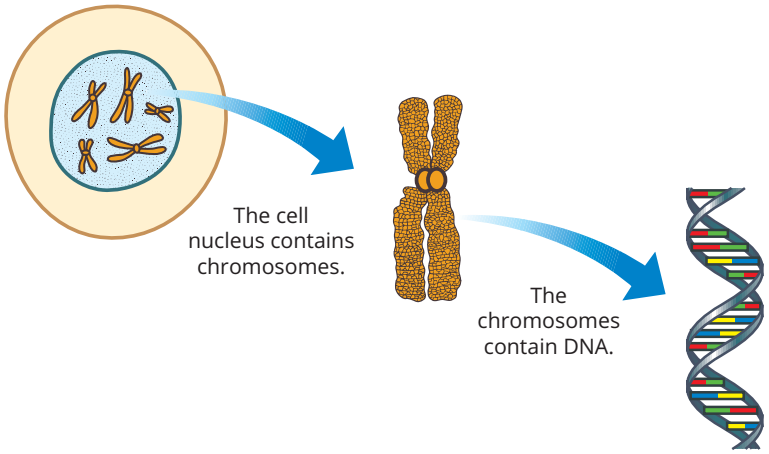


FIGURE 1.5.3 The nucleus of the cell contains chromosomes, which contain tightly packed DNA.

Not all cells have a nucleus

Not all cells have a nucleus. For example, the DNA of bacteria is not packaged in a nucleus—it floats freely in the cell.

Another example is red blood cells, which carry oxygen around the body. Not having a nucleus allows red blood cells to carry more oxygen. They start off with a nucleus but lose it as they mature. This means that red blood cells cannot grow or reproduce; they survive for only 100–120 days.

Scifile

DNA storage

Inside the nucleus, DNA is neatly packaged into structures called chromosomes. If you stretched out all the DNA in a single human cell, it would be about 2 m long!

SC 2 CHECK YOUR UNDERSTANDING

Outline the main function of the nucleus.

Lesson review

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

1. Describe what the nucleus looks like in a typical cell diagram.
2. List the key cell functions that the nucleus controls.
3. Explain the key difference between how DNA is stored in eukaryotic cells and prokaryotic cells.
4. Explain the benefit of red blood cells lacking a nucleus.

1.6 Observing cells

Learning intention

To be able to use a microscope to observe and record images of plant cells

Success criteria

SC 1: I can use a microscope at a range of magnifications to observe and record features of plant cells.

SC 2: I can use microscopic observations to describe and compare plant cells.

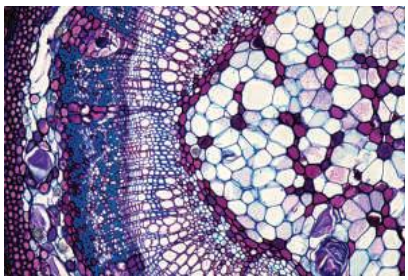


FIGURE 1.6.1 This light microscope image of a cross-section of a plant stem shows different types of cells.

SAFETY NOTE

- Iodine is harmful and also causes stains. Wear safety glasses and avoid contact with skin and clothes.

HINT

Check in with your teacher to make sure you have correctly prepared your slides and set up the microscope. You can also use Figure 1.4.1 to help you remember the names of the parts and their functions.

Introduction

Light microscopes continue to be used by scientists to study cells and their components, such as the image in Figure 1.6.1. Magnifications of up to 400 times can easily be obtained with a light microscope, and this is often enough to reveal not just the shape of cells but some of their internal structures as well.

In this practical investigation, you will use your microscopy skills to examine a range of cells and organisms.

Background

Earlier in the topic, you should have learnt how to use a light microscope. In this lesson, you will be using a microscope to observe some plant cells from onions and rhubarb. If you are careful, you should be able to observe and draw some basic parts of the cells.

Aim

To test your microscopy skills and observe and compare plant cells

Materials

- slices of onion and rhubarb leaf stalk
- a few drops of iodine
- a few drops of water
- microscope and lamp
- filter paper
- 2 microscope slides and coverslips
- eye-dropper and forceps
- safety glasses

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. Carefully peel a thin (one-cell thick) layer of onion skin from an onion.
2. Use tweezers to place a small sample of the onion skin onto a glass microscope slide. Make sure the skin is lying flat, rather than folded.
3. Place a drop of water and a drop of iodine on the onion skin sample and carefully cover with a coverslip. The iodine stains the cells and makes them easier to see.
   See Hint.

4 Use the microscope to observe the cells at two different magnifications.

5 Carefully peel a thin layer of skin from the outside of the rhubarb leaf stalk. Repeat the procedure that you used for preparing the onion skin sample, but do not use the iodine stain.

SkillBuilder

Increasing magnification

When you want to change the magnification of a microscope from a lower magnification to a higher magnification, follow these steps.

1 Make sure that the specimen, or the part of the specimen that you want to look at, is in the centre of the field of view.

2 Focus the specimen on low power.

3 Without moving anything else, carefully turn the objective lenses around so that the one with the higher magnification is above the slide.

4 Look through the eyepiece. If the specimen is not in focus, use the (fine) focus to sharpen the image.

Example

Pari focused in on a sliver of onion using the 4× objective lens. Combined with a standard 10× eyepiece lens this gave a total magnification of 40×. She then turned the objective lens so that the 10× lens was above the specimen. Using the fine focus knob, she was able to obtain a sharply focused image with a magnification of 100×.

An important skill when using a microscope is to be able to represent what is observed through the microscope.

SkillBuilder

Drawing from the microscope

Scientific drawings of cells

Scientific drawings and diagrams are an important way to record and communicate information, such as your observations of cells when looking through a microscope. When drawing specimens, you should:

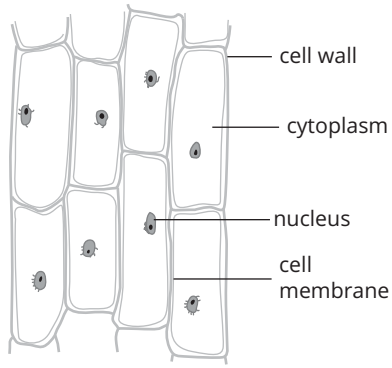
- use white, unlined paper
- draw in lead pencil only
- draw simple and clear lines
- make your drawing large enough to see detail (10 cm × 10 cm) if possible
- draw two-dimensional shapes (not in 3D)
- use small dots (called stippling) rather than shading to show depth
- draw one cell or a few cells to represent the whole sample; there is no need to draw every cell in the field of view
- draw only what you can see, not what you think you should see (e.g. organelles that are too small to see through a light microscope)

- write clear labels for the features you want to highlight; place labels on either side of the drawing
- rule a straight line between each label and its feature; make sure the label lines do not cross over each other
- write the name of the specimen and the magnification at which it was observed above the drawing.

Example

Lucas observed onion cells through a microscope and created the following scientific drawing.

Onion cell
[400×]



HINT

To calculate total magnification, multiply the magnification of the eyepiece (ocular lens) by the magnification of the objective lens.

Results

In your notebook, draw a few cells at the higher magnification. On your diagram, record the type of cell you have drawn and the magnification used.

Conclusion

Write your conclusion to the experiment by answering the following questions in your notebook.

1. List the parts of the cell you were able to see clearly in the onion skin cell and in the rhubarb skin cell.
2. Explain why there may be parts of the cell that you were not able to observe.
3. Compare and contrast the appearance of the onion cells and rhubarb cells.
4. Propose a reason why iodine was used to stain the onion cells but not the rhubarb cells.

1.7 The roles of the cell wall and cell membrane

Lesson overview

Imagine collecting the shopping in a paper bag. The bag helps keep everything together. Without it, the shopping will just fall out onto the floor. A cell membrane is a bit like a paper shopping bag. It keeps things together, but there are some things, like water, that can pass through the bag from the inside out, or from the outside in.

If you wanted to stack a lot of shopping, it might be better to put the bags inside a cardboard box. The box provides strength, and it is much easier to stack boxes on top of each other than it is to stack bags. The box is a bit like a cell wall. It gives the cell a fixed shape and protects the materials inside the cell, including the membrane.

In this lesson, you will learn about the functions of the cell membrane and the cell wall. You will also discover why plants cells need cell walls but animal cells do not.

SC 1	I can identify the cell membrane and cell wall of a cell from a photomicrograph, model or other visual representation

Learning intention

To understand the roles of the cell wall and cell membrane in the function of cells

Success criteria

SC 1: I can identify the cell membrane and cell wall of a cell from a photomicrograph, model or other visual representation.

SC 2: I can describe the functions of cell membranes and cell walls.

SC 3: I can compare the functions of cell membranes and cell walls.

Cells in animals

Cells in animals do not have a **cell wall**. This allows the cell to be flexible. Think of red blood cells, which need to squeeze through different places in the body to deliver oxygen. Many animals that need to have support have some form of skeleton or shell that can provide that structure. The **cell membrane** can be seen in diagrams (Figure 1.7.1) and micrographs (Figure 1.7.2) as the edge or border of the cell.

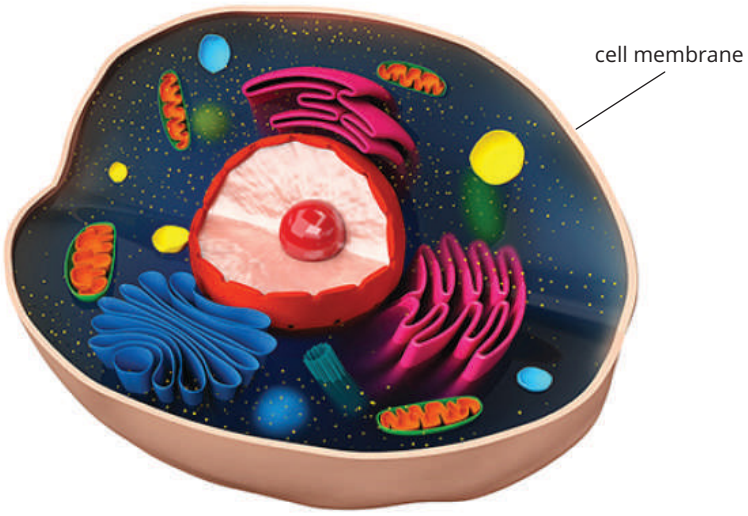


FIGURE 1.7.1 A representation of a typical animal cell

KEY TERMS

cell wall a rigid layer on the outside of a plant cell or prokaryotic cell; provides the skeleton of a plant

cell membrane a thin layer that separates the cell from its surroundings and controls what can move in and out of the cell

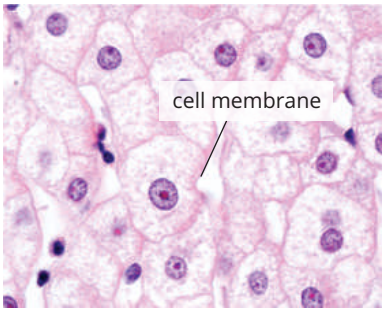


FIGURE 1.7.2 A micrograph showing stained human liver cells; the cell membrane is the structure surrounding each cell.

Cells in plants

Plant cells have a cell wall and a cell membrane. In plant cells, it can be difficult to see the cell membrane as separate from the cell wall. The cell wall is the thicker structure surrounding the plant cell, and the cell membrane is inside the cell wall, as shown in the diagram (Figure 1.7.3) and photo (Figure 1.7.4).

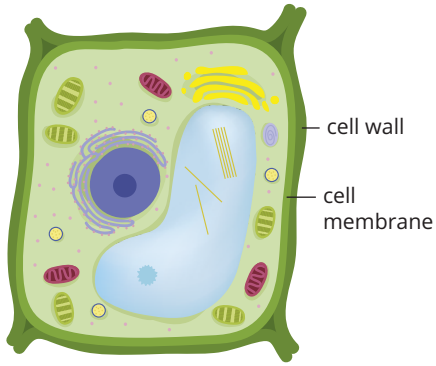


FIGURE 1.7.3 A diagram showing the cell wall and cell membrane of a plant cell

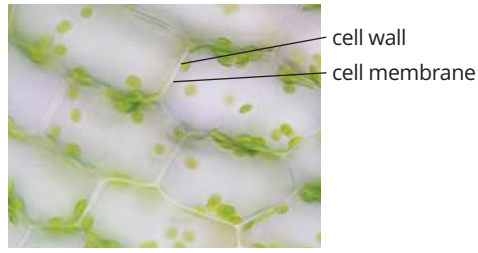


FIGURE 1.7.4 A micrograph of leaf cells under a light microscope; the cell wall is the thicker structure surrounding the cell, and the cell membrane is inside the cell wall.

SC 1 CHECK YOUR UNDERSTANDING

Describe the position of the cell wall and cell membrane in a plant cell.

SC 2 I can describe the functions of cell membranes and cell walls

KEY TERMS

semi-permeable membrane a thin layer of material that only certain particles can pass through

osmosis the process by which particles of water pass through a semi-permeable membrane from a less concentrated solution into a more concentrated one

Cell membrane functions

Every cell is enclosed by a 'skin' that keeps it separate from the environment around it. This is the cell membrane (Figure 1.7.5). The cell membrane contains all the cellular components and controls what comes into and goes out of the cell. It is a **semi-permeable membrane** because only some substances can pass through the membrane, and some cannot.

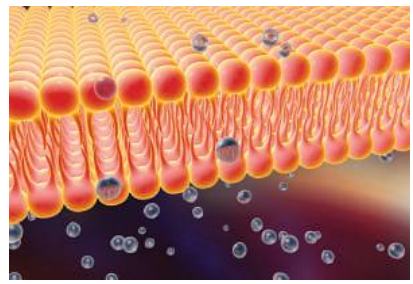


FIGURE 1.7.5 A close-up cross-section of a cell membrane; some substances are moving into and out of the cell through the cell membrane.

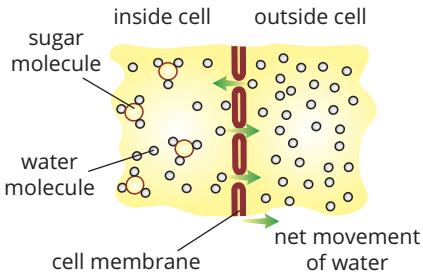


FIGURE 1.7.6 A representation of osmosis; the smaller water molecules can pass through the membrane, while the larger sugar molecules cannot.

Controlling what moves into and out of a cell

The cell membrane controls what can go in and out of the cell, which is why it is also known as a semi-permeable membrane. It acts like a fence surrounding a block of land with gates that allow only some things to move in or out. In Figure 1.7.6, you can see water molecules are able to pass in and out of the cell, but glucose molecules cannot. The movement of water molecules in and out of the cell is known as **osmosis**.

Cell wall functions

All cells have a cell membrane, but plant cells and fungal cells also have a cell wall that surrounds the cell membrane. The cell wall helps support the plant or fungus and gives it shape (Figure 1.7.7).

Plants and fungi need this extra support to protect them from external environmental exposure or physical damage. This rigid (or stiff) structure means that the cells are not very flexible and cannot easily change shape.

Cell walls need to be semi-permeable to allow for transport of substances, but they do not control what goes in and out of the cell in the way that cell membranes do.

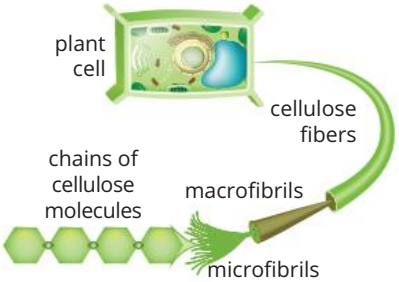


FIGURE 1.7.7 Plant cell walls have a more rigid structure and are made up of a sugar molecule known as cellulose.

SC 2 CHECK YOUR UNDERSTANDING

Define the term 'semi-permeable membrane'.

SC 3 I can compare the functions of cell membranes and cell walls

TABLE 1.7.1 A comparison of the cell membrane and cell wall

Cell membrane	Cell wall
in all cells	in plant and fungi cells
surrounds the contents of the cell	surrounds the cell membrane
flexible	rigid
controls what goes into and out of the cell (semi-permeable)	does not control what goes into and out of the cell (fully permeable)
provides a physical barrier around the cell	provides structural support and protection (mostly made of cellulose, which can be very strong)

SC 3 CHECK YOUR UNDERSTANDING

Explain the difference between how the cell membrane and the cell wall let substances in and out of the cell.

Lesson review

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

1. Describe the purpose of the cell wall in plant cells.
2. Name the term used to describe the movement of water in and out of the cell.
3. Explain the differences in appearance and location between the cell membrane and the cell wall.
4. Outline how the cell membrane and cell wall work together in plant cells.

1.8 Investigating the action of a cell membrane

Learning intention

To be able to investigate the action of a cell membrane

Success criteria

SC 1: I can develop a prediction around the movement of water through a membrane.

SC 2: I can measure and record masses and volumes with a high level of precision.

SC 3: I can use knowledge of cell membranes to explain experimental results.

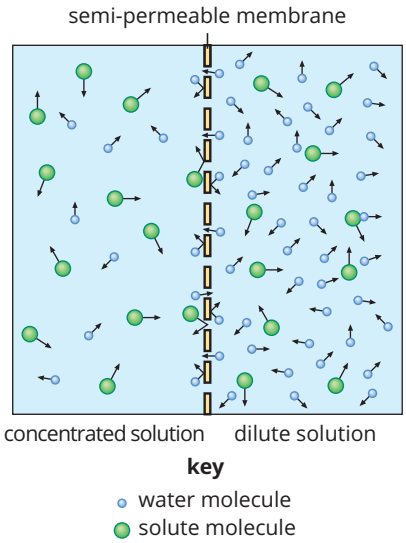


FIGURE 1.8.1 Particles involved in osmosis through a membrane

Introduction

Cell membranes are a vital part of all plant and animal cells. They control what goes in, what stays in and what leaves the cell. The cell membrane can be thought of as the 'skin' of the cell.

The process of water moving into and out of a cell is called osmosis (Figure 1.8.1). Chemicals dissolved in water (e.g. salt) affect how the water passes into and out of the cell. This process is vital for the balance of chemicals inside the cell.

In this practical investigation, you will investigate how adding salt to water affects the flow of water into and out of a cell through a membrane.

Background

Hens' eggs contain only one cell. This cell is surrounded by the yellow yolk of the egg, which is a collection of nutrients, including fat, proteins and carbohydrates. The egg white is 90% water, with proteins and other chemicals dissolved in the water.

When you break an egg, you can sometimes see a very thin skin just under the shell (Figure 1.8.2). This is not a cell membrane; it is the membrane of the egg. Nevertheless, an egg's membrane behaves in a similar way to a cell membrane. In this experiment, these similarities are taken advantage of to investigate the action of a cell membrane using an egg.

Osmosis

Membranes like the one that surrounds an egg allow only very small particles, like water, to pass through. These membranes are called semi-permeable membranes because they allow some substances to cross but not others. The process of water passing through a membrane is called osmosis. The overall direction of the flow of water through the membrane is from the side with a lower concentration of solute to the side with a higher concentration of other chemicals, as shown in the Figure 1.8.3. As water passes through the membrane to the side with a higher concentration of chemicals, that concentration will be reduced.

Aim

To investigate the movement of water through a cell membrane

Prediction

Read the method and write a prediction for what will happen to the mass of the eggs (one in salt water and one in distilled water) and the volumes of water in this experiment.

Materials

- 2 eggs
- 500 mL white vinegar
- 1 tablespoon salt
- 500 mL distilled water (pure water with no chemicals dissolved in it)
- electronic balance
- 200 mL measuring cylinder
- container large enough to hold two eggs immersed in vinegar
- 2 × 500 mL beakers
- plastic 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.

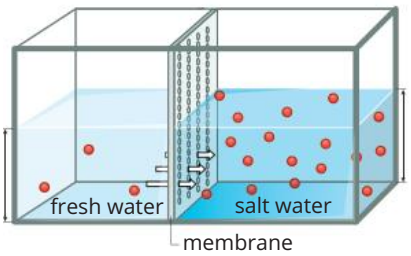
Method

1. In your notebook, copy Tables 1.8.1 and 1.8.2 and their titles from the Results section.
2. Place the two eggs in a container of vinegar so that both eggs are completely covered.
3. Leave the eggs undisturbed for two days. By this time, the vinegar should have dissolved the eggshell. The membrane inside the shell becomes the outer layer of the egg.
4. Carefully remove the eggs from the vinegar and rinse them. Pat them dry with paper towel.
5. Label the two glass beakers 'salt water' and 'distilled water'.
6. Make a concentrated salt solution by adding a tablespoon of salt to 250 mL of distilled water.
7. Measure out 200 mL of the salt water and pour it into the beaker labelled 'salt water'.
8. Measure out 200 mL of the distilled water and pour it into the beaker labelled 'distilled water'.



FIGURE 1.8.2 The membrane of the egg is just under the shell.

GO TO
Toolkit section 1.2, Making predictions from observations



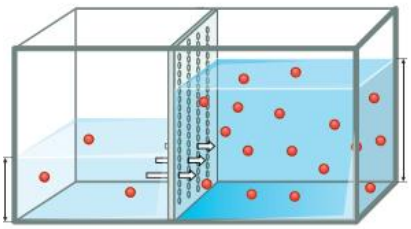


FIGURE 1.8.3 Water moves through a membrane to the area where there is a higher concentration of other chemicals (shown by the red dots).

SAFETY NOTES

- Wear eye protection when using the vinegar in the first part of the experiment.
- Make sure you let your teacher know if you have food allergies and a different experiment can be conducted.

9 Use a balance to find the mass of each egg. Record each mass in the Day 0 column of Table 1.8.1.

10 Place one egg in each beaker of water and cover with plastic wrap.

11 Each day, for the next three days, measure and record the mass of the eggs.

12 On Day 3, measure and record the volume of water remaining in each of the beakers. Record this in the Day 3 column of Table 1.8.2.

Results

Record your results in your notebook/in the tables below.

TABLE 1.8.1 Changes in the mass of eggs in salt water and distilled water

Treatment	Mass of egg (g)				
	Day 0	Day 1	Day 2	Day 3	Total change in mass (g)
distilled water					
salt water					

HINT

When you measure the mass of the eggs, take only one egg at a time from the solutions. This will ensure that each egg is returned to the correct solution.

TABLE 1.8.2 Changes in the volume of salt water and distilled water

Treatment	Volume of water (mL)		
	Day 0	Day 3	Total change in volume (g)
distilled water	200		
salt water	200		

Conclusion

Answer the following questions in your notebook to construct a conclusion to the experiment.

1 Describe any changes that took place in the two eggs.

2 Describe any change in the volume of the water in the two beakers.

3 Compare the actual results with your prediction.

4 Consider the process of osmosis and explain what you think was happening to the eggs and the role the membrane played.

GO TO
Toolkit section 4.2, Evaluating validity

Evaluation

Evaluate your investigation and the quality of the data with reference to readability, validity and accuracy.

1.9 The functions of the cytoplasm in cells

Lesson overview

In this topic, you should be starting to put together your knowledge and understanding of the various parts of animal and plant cells.

Cells are mini systems in which each component works together. To do this, the components have to 'live' together, and the place where they do this is called the cytoplasm of the cell. Cytoplasm was discovered around 1865 when microscopes were able to create sufficiently detailed images.

The word 'cytoplasm' comes from 'cyto-', for cell, and '-plasm', for being formed into a shape.

In this lesson, you will learn about the location, contents and functions of the cytoplasm (Figure 1.9.1).

SC 1 I can identify the cytoplasm of a cell from a photomicrograph, model or other visual representation

Cells are filled with a jelly-like mixture of fluid and organelles called the cytoplasm. The cytoplasm includes everything inside the cell membrane except the nucleus (Figure 1.9.2). The liquid part of the cytoplasm is called the **cytosol**.

Finding the cytoplasm

In diagrams of cells, the cytoplasm is often shown as the background colour of the cell, as you can see in the micrograph of the moss cells (Figure 1.9.2). Although in diagrams the cytoplasm may appear to be the background of the cell, it is important to remember that the cytoplasm is everything inside the cell membrane, including the fluid (cytosol) and all the organelles except the nucleus.

SC 1 CHECK YOUR UNDERSTANDING

What structures can be observed in the cytoplasm?

SC 2 I can describe the components that are contained in the cytoplasm of a cell

The cytoplasm is mostly made up of water, salts, proteins and organelles. The organelles contained in the cytoplasm are:

- ribosomes, where proteins are made
- mitochondria, where chemical energy from food is transformed into energy for the cell
- **chloroplasts**, where sunlight is used to create nutrients.

Learning intention

To understand the role of the cytoplasm in cellular function

Success criteria

SC 1: I can identify the cytoplasm of a cell from a photomicrograph, model or other visual representation.

SC 2: I can describe the components that are contained in the cytoplasm of a cell.

SC 3: I can describe the functions of the cytoplasm of a cell.



FIGURE 1.9.1 The cytoplasm is enclosed by the membrane of the cell.

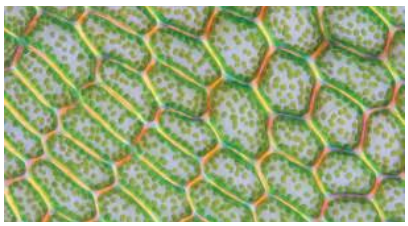


FIGURE 1.9.2 Moss plant cells seen through a light microscope; the cytoplasm is everything inside the cell membrane except the nucleus.

KEY TERMS

cytosol fluid in the cytoplasm of a cell

chloroplast an organelle within the cell where photosynthesis takes place

KEY TERM

cytoskeleton a network of proteins in the cytoplasm

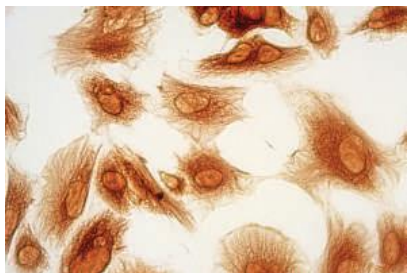


FIGURE 1.9.3 A light microscope image of stromal cells, which connect tissue in organs. The brown stain helps to show the protein cytoskeleton in the cells.

Scifile

Fake limbs

The *Amoeba proteus* can use its cytoskeleton to create fake limbs known as pseudopods. The pseudopods allow the amoeba to move around and bring it closer to nutrient sources.



Supporting the cell

The cytoplasm fills out a cell and gives it shape and support. A network of proteins in the cytoplasm acts like a cellular 'skeleton', providing structure, moving and holding organelles in place. This network of proteins in the cytoplasm is known as the **cytoskeleton**, which can be seen in the cells in Figure 1.9.3.

SC 2 CHECK YOUR UNDERSTANDING

List the organelles within the cytoplasm of the cell and briefly outline their function.

SC 3 I can describe the functions of the cytoplasm of a cell

Many important cellular processes occur in the organelles contained in the cytoplasm, some of which are chemical reactions and processes involved in cell growth.

The cytoplasm also allows materials to move around the cell—material taken in from outside the cell travels through the cytoplasm to reach the organelles, and products created by the organelles travel through the cytoplasm to exit the cell through the cell membrane.

How does the cytoplasm move things?

Parts of the cytoplasm can move around to change the position of organelles. An example is in plant cells where chloroplasts, which use sunlight to create nutrients, use the cytoskeleton to move to the areas of the cell that are exposed to the most sunlight.

Some unicellular organisms can use their cytoplasm for movement as the cells respond to the environment around them. For the whole cell to travel, the cytoplasm can be extended to move in one direction.

SC 3 CHECK YOUR UNDERSTANDING

Explain one key function of the cytoplasm in the cell.

Lesson review

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

1. Define the term 'cytoplasm'.
2. Name one component in the cytoplasm.
3. Describe what the cytoplasm looks like when viewing cells under a light microscope.
4. The cytoplasm is made up of different parts. Identify the key features of the:
   a. cytosol
   b. cytoskeleton.
5. The cytoplasm contains a range of different substances. Explain the importance of the cytoplasm having this feature.

1.10 The functions of mitochondria and chloroplasts in cells

Lesson overview

Humans, like all animals, survive by eating plants, or eating animals that have eaten plants, or eating animals that have eaten animals that have eaten plants. Only plants can create food from carbon dioxide and water, with help from sunlight.

Within their cells, both plants and animals have specialised organelles known as mitochondria to help make energy for their cells from glucose. Plants have organelles called chloroplasts to assist in creating food (glucose) from the Sun's light energy.

In this lesson, you will learn about how chloroplasts and mitochondria carry out their roles in cells and how they have more things in common than you might think.

SC 1	I can identify the mitochondria and chloroplasts of a cell from a photomicrograph, model or other visual representation

Learning intention

To understand the roles of mitochondria and chloroplasts in cellular function

Success criteria

SC 1: I can identify the mitochondria and chloroplasts of a cell from a photomicrograph, model or other visual representation.

SC 2: I can describe the functions of the mitochondria and chloroplasts of a cell.

SC 3: I can compare and contrast the presence and functions of the mitochondria and chloroplasts in cells.

KEY TERMS

mitochondria organelles where energy is released from food through the process of cellular respiration

Finding mitochondria

Mitochondria (singular mitochondrion) are only 0.5–3 µm long, so you need an electron microscope to see them in detail. Cells that require a lot of energy can contain more than 1000 mitochondria.

Mitochondria are made up of an outer membrane and an inner membrane that has many folds. In diagrams, mitochondria often have an oval shape with folds in the middle (Figure 1.10.1). In cells, the inner membrane folds can be seen at high magnification using an electron microscope (Figure 1.10.2).

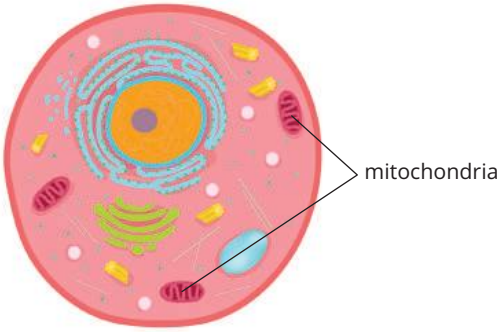


FIGURE 1.10.1 A diagram of an animal cell showing the mitochondria

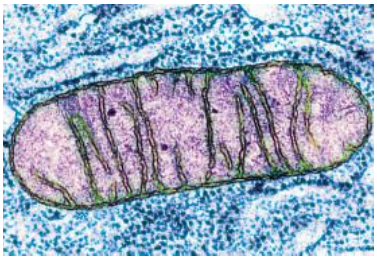


FIGURE 1.10.2 A micrograph of a mitochondrion seen through a transmission electron microscope; the membranes of the mitochondrion are coloured green (long 'tubular' shapes).

Finding chloroplasts

Chloroplasts are approximately 5–7 µm long. They are slightly larger than mitochondria and can be seen through a light microscope.

In diagrams (Figure 1.10.3), chloroplasts are represented as green oval shapes with lines across the middle, which represent the stacked compartments inside the chloroplasts.

Chloroplasts appear green because of the large amounts of **chlorophyll** they contain. Because chloroplasts are green, they can often be seen through a light microscope without staining (Figure 1.10.4).

KEY TERM

chlorophyll the substance in plant leaves that make leaves green and collects energy from the Sun for photosynthesis

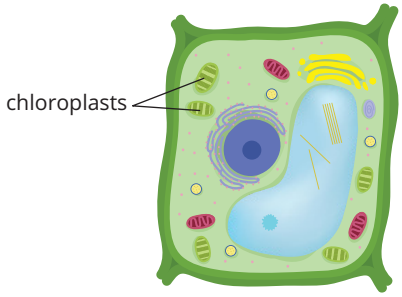


FIGURE 1.10.3 A diagram of a plant cell showing the chloroplasts scattered throughout the cytoplasm



FIGURE 1.10.4 An image of cells in a leaf seen under a light microscope; each cell contains many green chloroplasts.



FIGURE 1.10.5 Two chloroplasts in the leaf cell of a pea plant seen through a transmission electron microscope; the image has been coloured, and the membranes that make up the inner compartments are shown in yellow (long, thin 'stacked' lines).

Chloroplasts are surrounded by an outer membrane and contain compartments that are made from folded membranes. These stacked compartments can be seen in cross-section images of chloroplasts using high-powered microscopes (Figure 1.10.5).

SC 1 CHECK YOUR UNDERSTANDING

Explain why chloroplast are easier to view than mitochondria within the cell.

SC 2 I can describe the functions of the mitochondria and chloroplasts of a cell

The function of mitochondria

Mitochondria are organelles that can convert glucose from food into chemical energy that the cell can use. Mitochondria release energy in a series of chemical reactions called cellular respiration. The type of cellular respiration that takes place in the mitochondria is called aerobic respiration because it involves oxygen.

Mitochondria are present in both plant and animal cells. The number of mitochondria in a cell is related to how much energy the cell needs. Very active cells, such as heart muscle cells and neurons in the brain, have thousands of mitochondria. The structure of mitochondria is complex with an inner and outer membrane that act together to control the movement of chemicals within the mitochondria (Figure 1.10.6).



FIGURE 1.10.6 A cutaway representation of a mitochondrion showing the inner (bright-yellow wavy structure) and outer (beige) membranes

The function of chloroplasts

Chloroplasts trap energy from sunlight and use it to make food for the plant. This process is called **photosynthesis** (Figure 1.10.7).

KEY TERM

photosynthesis the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from sunlight

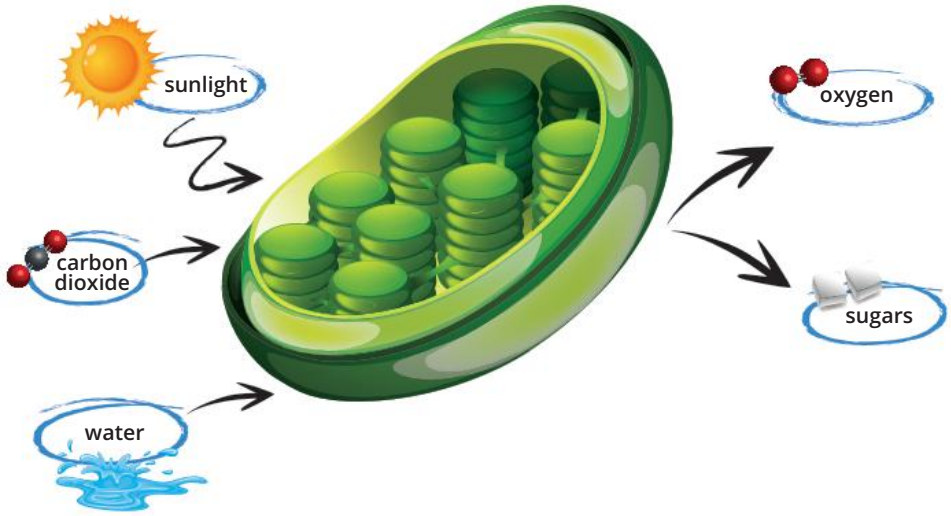


FIGURE 1.10.7 The process of photosynthesis; the inputs for photosynthesis are water and carbon dioxide. The outputs are food in the form of sugars (nutrients for the plant) and oxygen.

Chloroplasts are typically located in the cells of plant leaves and stems. The green colour of plants is from a pigment inside chloroplasts called chlorophyll. Chloroplasts are present in plants and many protists (single-celled eukaryotic organisms) but not in animals or fungi.

SC 2 CHECK YOUR UNDERSTANDING

Describe the function of chloroplasts within plant cells.

SC 3 I can compare and contrast the presence and functions of the mitochondria and chloroplasts in cells

Similarities between mitochondria and chloroplasts

Look at Figure 1.10.8. You will see that mitochondria and chloroplasts both have an inner and outer membrane and have structures inside the inner membrane. Chemical processes occur within these structures, so both mitochondria and chloroplasts act like mini factories, with inputs (energy and/or substances going in) and outputs (energy and/or substances going out).

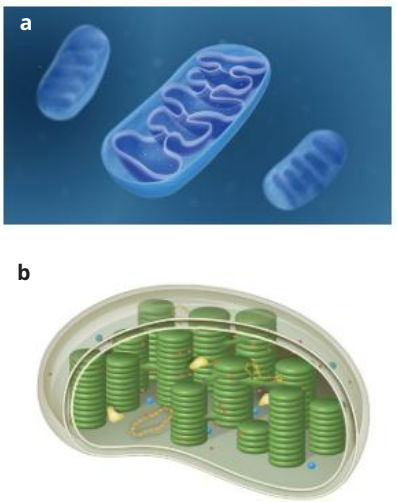


FIGURE 1.10.8 (a) A cross-section illustration of a mitochondrion showing its internal 'wavy' structure; (b) a cross-section illustration of a chloroplast showing its internal stacked structures

Scifile

The origins of mitochondria and chloroplasts

Scientists have long proposed that mitochondria and chloroplasts originated as unicellular prokaryotic organisms that were engulfed by a larger cell. Both organelles contain their own DNA, have cell membranes, and reproduce in a way similar to prokaryotic organisms, supporting this theory.

Differences between mitochondria and chloroplasts

The main difference between mitochondria and chloroplasts is the processes occurring inside them. Chloroplasts use carbon dioxide (CO_2) and water (H_2O) to make glucose ($C_6H_{12}O_6$) as 'food' for the cell. This process is called photosynthesis. Photosynthesis requires sunlight and produces oxygen (O_2) as a by-product.

Mitochondria convert glucose and oxygen back to carbon dioxide and water, releasing chemical energy in the form of a chemical called ATP (adenosine triphosphate), which can be used by the organism. This process is called cellular respiration.

From this, it should be clear that the chemical action of mitochondria and the chemical action of chloroplasts are almost opposite processes (Figure 1.10.9).

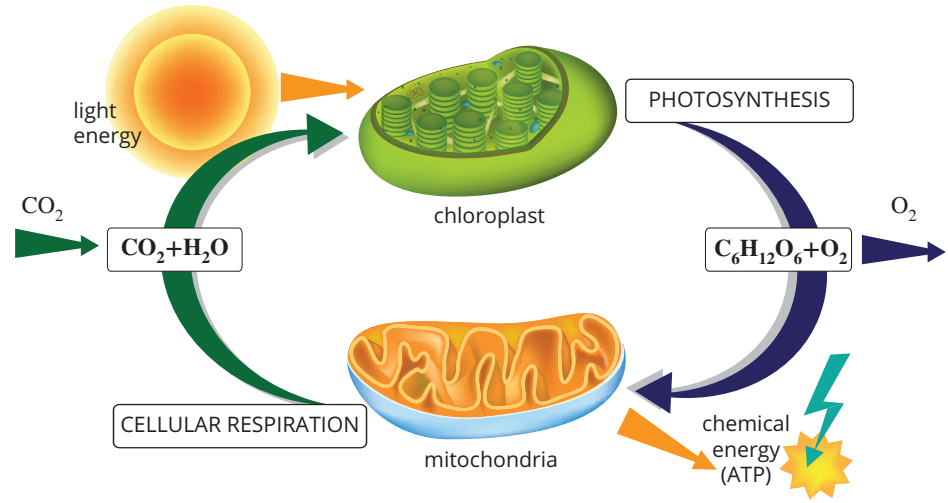


FIGURE 1.10.9 The relationship between the chemical processes occurring in mitochondria and chloroplasts

SC 3 CHECK YOUR UNDERSTANDING

Describe the chemical relationship between mitochondria and chloroplasts within plant cells.

Lesson review

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

1. Identify the types of microscopes required to view mitochondria and chloroplast.
2. What colour would chloroplasts be when viewing untreated plant cells under a simple microscope?
3. Identify the cell types that contain chloroplasts.
4. Identify and briefly explain the two different processes that occur in mitochondria and chloroplasts.
5. Emad was viewing different types of body cells under the microscope. He recorded the approximate number of organelles that he saw in each type of cell viewed. He noted that the skin cells and nerve cells (also known as neurons) had very different numbers of mitochondria. Predict which cells that Emad viewed would have more mitochondria and explain why this would be the case.

1.11 The functions of vacuoles in cells

Lesson overview

Most systems require some storage facility. Bedrooms have wardrobes, kitchens have fridges, and houses have water tanks and rubbish bins. Cells are just the same. There are many substances going in and out of cells, and there are new materials being created all the time. Vacuoles are the way that cells solve their storage issues.

In this lesson, you will learn about how vacuoles are a necessary part of plant and animal cells, how they act as storage for a range of materials and how they can also provide much needed support and protection for the cell.

SC 1 I can identify the vacuoles of a cell from a photomicrograph, model or other visual representation

Vacuoles are in most cells, but the number and size of vacuoles is different in plant and animal cells. Plant cells have a single large vacuole that can take up most of the space inside the cell (Figure 1.11.1), whereas animal cells can have many smaller vacuoles that can appear and disappear depending on the needs of the cell (Figure 1.11.2).

It can be difficult to tell the difference between a vacuole and the cytoplasm when viewing a cell through a light microscope. This is because if the vacuole is filled with fluid, it is transparent and varies in shape and size between cells. In plant cells, the vacuole can usually be identified as a large space in the middle of the cell, with other organelles pushed to the side of it (Figure 1.11.3).

Learning intention

To understand the role of vacuoles in cellular function

Success criteria

SC 1: I can identify the vacuoles of a cell from a photomicrograph, model or other visual representation.

SC 2: I can describe the functions of vacuoles in plant and animal cells.

KEY TERM

vacuole a small structure in animal cells that may contain wastes or chemicals, or a large sap-filled structure in plant cells that stores water, wastes and nutrients

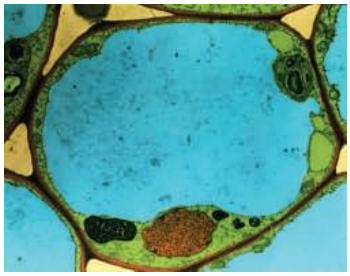


FIGURE 1.11.1 The vacuole of this plant cell (coloured blue in this micrograph) fills almost all the cell.



FIGURE 1.11.2 This unicellular organism (a protozoan) contains several vacuoles that can change size.

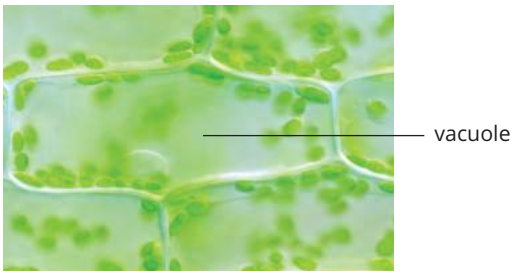


FIGURE 1.11.3 Plant cells seen through a light microscope; the vacuole is the large space in the middle of the cell pushing the green chloroplasts towards the edge of the cell.

SC 1 CHECK YOUR UNDERSTANDING

Identify how scientists can distinguish the vacuole from the cytoplasm when viewing plant cells under a microscope.

SC 2 I can describe the functions of vacuoles in plant and animal cells

Vacuoles are organelles that are involved in storage, but they have many functions in plant and animal cells.

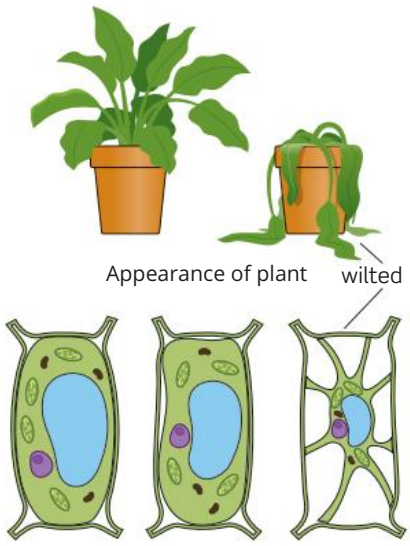


FIGURE 1.11.4 As the vacuoles in a plant's cells lose water, turgor pressure is reduced, which causes the stems of the plant to lose strength and the plant to wilt.

Vacuoles in plant cells

In plant cells, vacuoles contain a solution called sap. The vacuole is separated from the rest of the cytoplasm by a semi-permeable membrane, and this controls the contents of the sap, which include waste materials, pigments that give the plant colour, nutrients for growth and even toxins to help protect the plant from being eaten by insects or other animals.

The vacuole of plant cells also provides structure. When it is full, the vacuole presses against the plant cell wall and helps to keep the plant rigid and upright. This pressure is called turgor pressure. This effect can be seen when a plant has plenty of water and the turgor pressure is high. When the plant is lacking in water, the cells lose this support, and the plant wilts (Figure 1.11.4).

Vacuoles in animal cells

Not all animal cells contain vacuoles. In those that do, the vacuoles are much smaller than those in plants, and the cell can also contain many vacuoles. These vacuoles store materials depending on the needs of the cell. For example, the vacuoles in fat cells may contain lipids, which are the chemicals used to make fat.

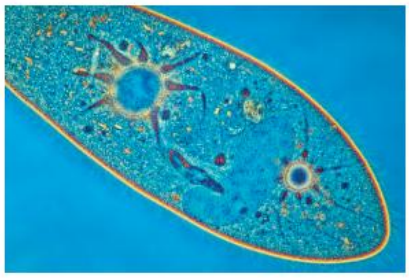


FIGURE 1.11.5 Two contractile vacuoles in a paramecium cell seen under a light microscope

Contractile vacuoles are often seen in unicellular organisms. These control the amount of water in the cell by increasing and decreasing size (Figure 1.11.5).

Some materials do not easily pass in and out of the cell through the cell membrane. The vacuoles also help these materials, such as nutrients, move into the cell and other materials, such as toxins, to move out of the cell. The vacuole acts like an exit 'waiting room' or an entry 'reception room' for the material. While they are in the vacuole, the material may be broken down into smaller particles.

SC 2 CHECK YOUR UNDERSTANDING

Describe what occurs when plant cell vacuoles are full.

Lesson review

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

1. Identify the substances that plant vacuoles contain.
2. State the key difference between the structure of the vacuole in plant cell and animal cells.
3. Explain the role of vacuoles in maintaining the functions of the cell.
4. During dry summer months, some plants can start to become wilted if they are not watered often. Explain why this may occur.

1.12 Comparing plant and animal cells

Lesson overview

Animals and plants, such as the bees and flowering plants have different survival needs.

Cells are the building blocks of all living things. Because animals and plants survive and grow in different ways, the cells in plants and animals must have different functions. You have learnt about many of these functions when investigating the functions of the various organelles in plant and animal cells in this topic.

In this lesson, you will bring together some of your knowledge and understanding of plant and animal cells to describe and explain their similarities and differences.

SC 1	I can distinguish animal and plant cells in a photomicrograph, model or other visual representation based on their appearance and organelles present

Learning intention

To understand the similarities and differences between animal and plant cells

Success criteria

SC 1: I can distinguish animal and plant cells in a photomicrograph, model or other visual representation based on their appearance and organelles present.

SC 2: I can compare and contrast animal and plant cells based on the functions of their organelles.

Viewing animal cell organelles

Organelles are only visible using a microscope. Some larger organelles, such as the nucleus, can be seen through a light microscope, but other organelles, such as mitochondria, are so small that they can only be seen with higher magnification through an electron microscope. Figure 1.12.1 shows a typical animal cell that would be seen using a light microscope, with some organelles visible.

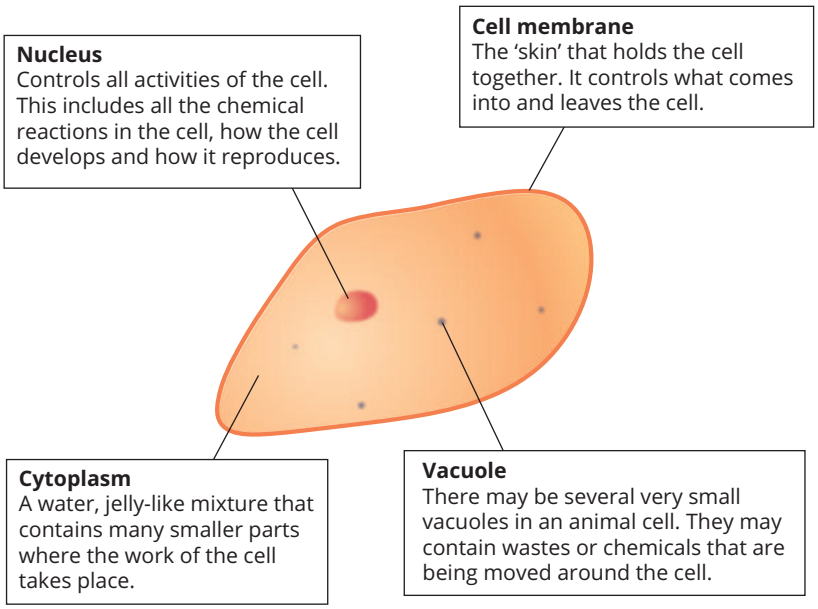


FIGURE 1.12.1 A diagram of an animal cell; the cell also contains smaller organelles that cannot be seen through a light microscope.

Viewing plant cell organelles

Plant cells are like animal cells, but because they function differently, they have some different structures, such as cell walls, chloroplasts and a single large vacuole. Plant cells are also larger than most animal cells. Remember that the first cells to be discovered were plant cells. Figure 1.12.2 shows the structure of a typical plant cell.

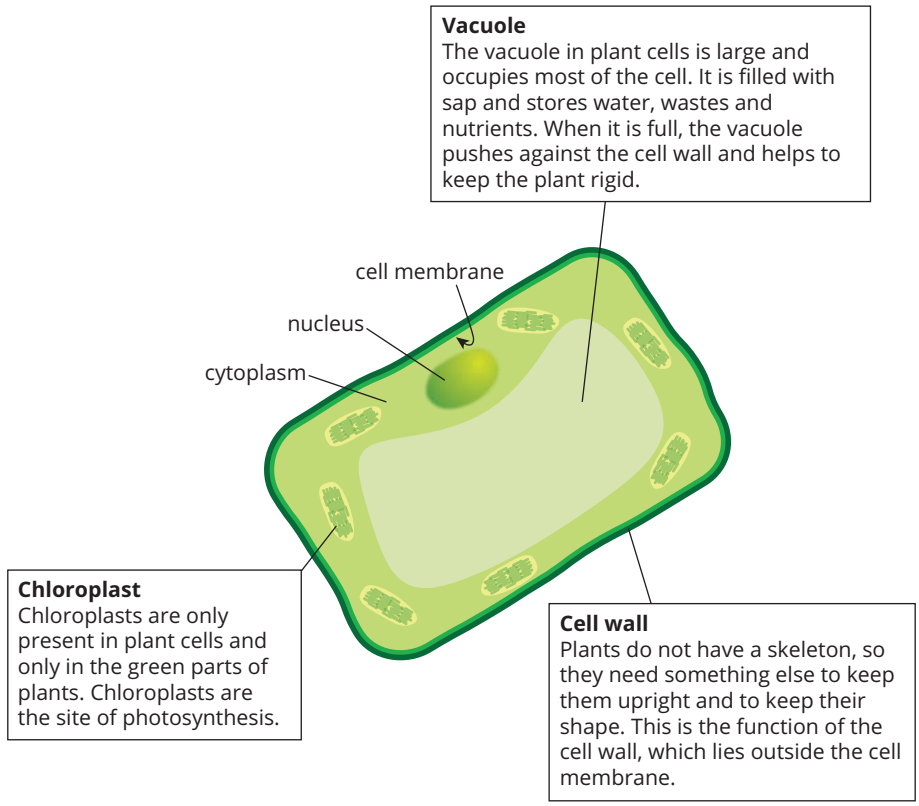


FIGURE 1.12.2 A diagram of the structures seen in a plant cell through a light microscope

SC 1 CHECK YOUR UNDERSTANDING

List the visible features of plant cells that distinguish them from animal cells.

SC 2 I can compare and contrast animal and plant cells based on the functions of their organelles

Organelles common to all eukaryotic cells

Each organelle has a special job or function. Some organelles are in both plant and animal cells, including:

- cell membrane
- cytoplasm
- nucleus
- mitochondria.

Animal cell organelles

Some organelles are only in animal cells. These are:

- **lysosomes**—'garbage disposal' units that get rid of waste from the cell
- **centrioles**—tiny tubes that help a cell split into two during cell division.

KEY TERMS

lysosome an organelle that gets rid of wastes from animal cells

centriole a barrel-shaped structure made from microtubes that is part of the cytoskeleton in animal cells

Plant cell organelles

Like animal cells, plants cells have a cell membrane, cytoplasm, nucleus and mitochondria. They also have the following organelles that are unique to plant cells.

- Cell wall—plant cells have a cell wall outside the cell membrane. The cell wall helps support the plant and gives it shape.
- Large vacuoles—both plant and animal cells have vacuoles, but the vacuole in a plant cell is much larger than in an animal cell.
- Chloroplasts—chloroplasts carry out photosynthesis and are in cells in the leaves of plants (Figure 1.12.3).

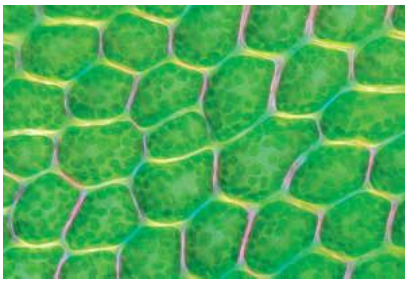


FIGURE 1.12.3 Chloroplasts and thick cell walls seen in a micrograph of moss cells viewed under a light microscope

Comparing plant and animal cells

Animal and plant cells are very similar. However, there are several differences between plant and animal cells. The main differences between the functions of the organelles in plant and animal cells are summarised in Table 1.12.1 and illustrated in Figure 1.12.4.

TABLE 1.12.1 A summary of the functions of organelles in animal and plant cells

Function	Organelle	Present in animal cells	Present in plant cells
Making and processing proteins	nucleus	✓	✓
	ribosomes	✓	✓
Energy and food production	mitochondria	✓	✓
	chloroplasts	✗	✓
Storage and structure	vacuole	✓ small	✓ large
	cell wall	✗	✓
	cell membrane	✓	✓

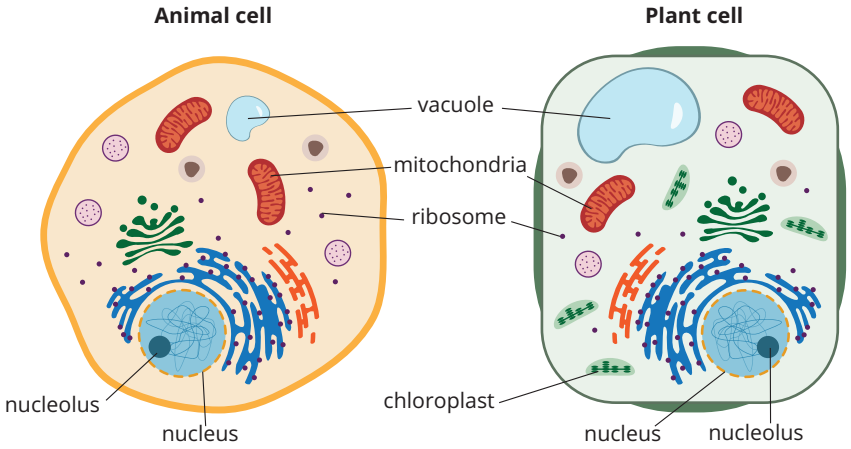


FIGURE 1.12.4 A diagram of an animal cell and a plant cell, showing their organelles

SCIENCE IN SOCIETY

Australian plants adapting to harsh conditions

When you observe plant cells under a microscope, you can see that they have many common features, but there are also differences depending on the type of plant and the cell's function. For example, leaf cells are packed with chloroplasts because they are the primary site of photosynthesis.

Root cells, on the other hand, often lack chloroplasts because they are located underground where there is no light. Instead, root cells have many mitochondria, the organelles responsible for producing energy. This allows the roots to absorb water and nutrients efficiently.

In Australia, researchers study the cells of various native plants to understand how they adapt to different environments. For example, the cells of desert plants like the spinifex grass have thick cell walls and large vacuoles to store water, helping them survive in arid (dry) conditions (Figure 1.12.5).

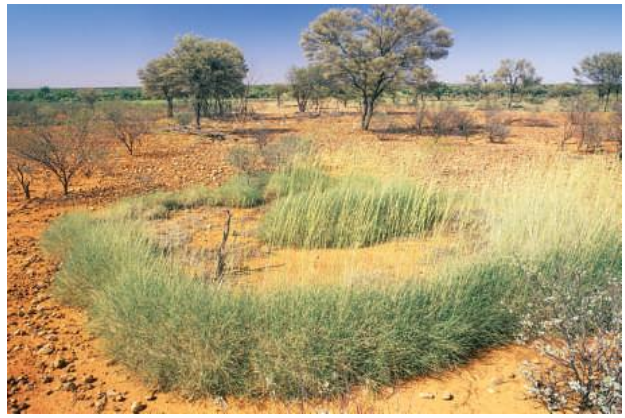


FIGURE 1.12.5 A ring of spinifex grass

By comparing different types of plant cells, scientists can learn how plants have evolved to thrive in various habitats. This knowledge is crucial for agriculture, conservation and understanding the impacts of climate change.

SC 2 CHECK YOUR UNDERSTANDING

List four features that are common to both plant and animal cells.

Lesson review

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

1. Identify the differences in structure and the vacuole storage in plant and animal cells.
2. Explain why both plant and animal cells require mitochondria.
3. Compare how plant and animal cells remove waste products.
4. Draw a Venn diagram with the headings 'animal only', 'plant only', 'both plant and animal' to compare and contrast the features of plant and animal cells.
5. Ebony was viewing cells under a light microscope. She noticed that the cells were rigid in shape and had many visible, oval-shaped organelles that were pushed to the exterior parts of the cell. What type of cells was Ebony most likely viewing? Explain your answer.

GO TO
Toolkit section 5.4, Graphic organisers: Venn diagrams

1.13 Organisms under the microscope

Introduction

Light microscopes continue to be used by scientists to study cells and unicellular organisms. Pond water contains a range of simple organisms, and at high magnification, cells, cell structures and organelles can be identified.

In this practical investigation, you will use your microscopy skills to examine a range of unicellular and simple multicellular organisms found in pond water, like the ones in Figure 1.13.1. You will have the opportunity to practise preparing a wet mount, obtaining high-quality observations at a range of magnifications and recording your observations using scientific drawing.

Learning intention

To be able to use microscopes to observe, record and compare unicellular and multicellular organisms

Success criteria

SC 1: I can use a microscope, with the appropriate magnification, to observe a variety of unicellular and multicellular organisms.

SC 2: I can record observations, including the magnification used, of unicellular and multicellular organisms using a microscope.

SC 3: I can evaluate the experimental method used to observe cells and organisms at the microscopic scale.

Background

Microscopes can be used to view tiny structures in pond water that are not visible to the naked eye, such as unicellular organisms and the organelles inside cells. The common pond water species *Euglena*, *Paramecium*, *Amoeba* and *Spirogyra* are useful organisms to view under the microscope because of their interesting and easy-to-view structures. *Euglena*, *Paramecium* and *Amoeba* are freshwater protists (single-celled organisms with a distinct nucleus), and *Spirogyra* is a type of green algae. Although *Euglena* is not a plant cell, it has chloroplasts that are thought to have been taken in from green algae.

Organisms that might be observed in pond water are shown in Figure 1.13.1. You can use these photos to help identify the organisms you observe.

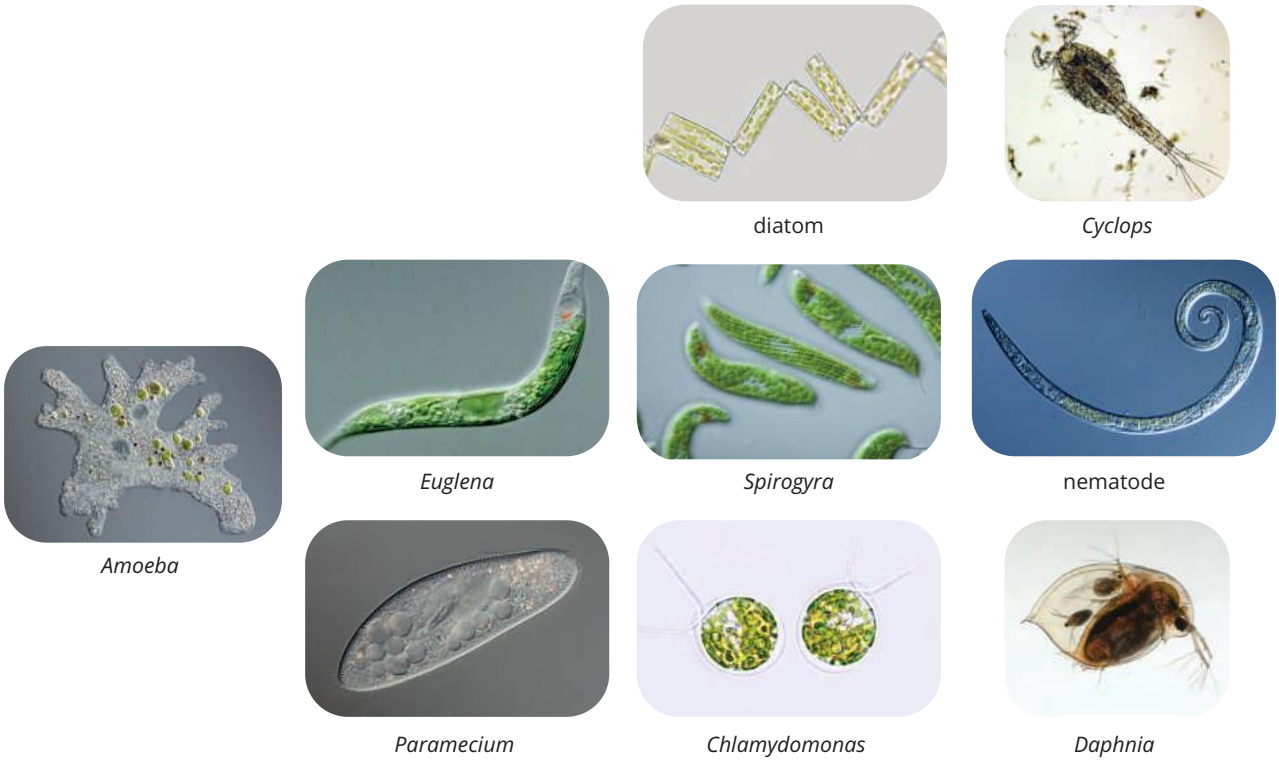


FIGURE 1.13.1 Various microscopic organisms found in pond water

Aim

To view unicellular and multicellular organisms under a light microscope and identify cell structures and organelles

SAFETY NOTES

- Handle glass slides and coverslips with care. If they break, inform your teacher and they will direct you on the correct method of disposal.
- Do not taste the pond water.

Materials

- sample of pond water, or separate samples of microorganisms such as *Euglena*, *Paramecium* and *Spirogyra*
- glass microscope slides
- glass coverslips
- plastic Pasteur pipettes
- forceps
- toothpicks
- cotton wool
- light microscope

GO TO
Toolkit section 2.1, Reducing risk

Assessment of risk

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

SkillBuilder

Preparing a wet mount

To prepare a wet mount, follow the steps below.

1. Place a drop of water onto the specimen on the microscope slide. If a stain is being used, it can be added to the drop of water at this stage.
2. Place one edge of the coverslip on the slide and lower it carefully using a toothpick, tweezers or your finger to avoid trapping air bubbles, as seen in Figure 1.13.2.

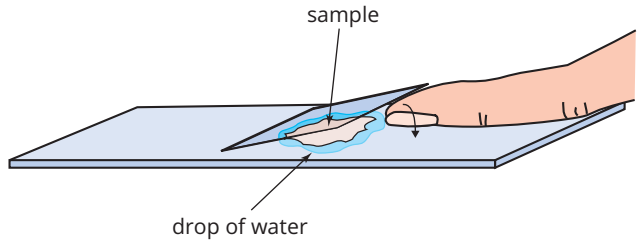


FIGURE 1.13.2 Lowering the coverslip onto the specimen

3. Soak up any excess water or stain with a piece of filter paper or tissue.
4. The specimen is now ready to be observed using the microscope.

Example

Pearl was preparing a wet mount to view under a light microscope (Figure 1.13.3). First, she placed her specimen on a microscope slide and added a drop of water on top of the specimen. She didn't need a stain for her specimen, but if she did, she would have added that at this stage. Next, she placed one edge of the coverslip on the slide and slowly lowered it with her finger. She was careful not to move too quickly, which can introduce air bubbles. Some liquid came out the sides of the coverslip, so she soaked up that excess liquid with a piece of tissue. Her wet mount was now ready to view under the microscope.



FIGURE 1.13.3 Using wet mounts for viewing specimens improves the quality of the image and protects the specimen from damage or dust from the environment.

Method

1. Place your sample in the centre of a slide. For the pond water, *Euglena* and *Paramecium*, use the plastic Pasteur pipette to place a drop of the sample onto the slide. For *Spirogyra*, use the forceps to place a segment of leaf onto the slide.
2. For specimens in water, tease out a few fibres of cotton wool and place them on the slide. The fibres will slow the movement of the organisms to help with observations.
3. Prepare the wet mount as described in the SkillBuilder: Preparing a wet mount.

HINT

Check with your teacher to make sure you have correctly prepared your slides and correctly set up the microscope.

4. Place the slide on the microscope stage. Make sure the light of your microscope is turned on.
5. Rotate the 4× objective lens over the stage. Adjust the coarse focus and then the fine focus until the sample can be seen clearly through the eyepiece.
6. Rotate the next-highest objective lens (10×) over the sample and adjust the focus.
7. Rotate the 40× objective lens over the sample and adjust the focus. Make some observations about what you see.

Results

Copy the table below in your notebook for each organism. In the table, record your observations. Include a sketch of the organism under observations, including any information about the structure and movement of the organism or any cell structures or organelles that you observed.

Organism name		Observations
Unicellular or multicellular		
Magnification		

HINT

To calculate total magnification, multiply the magnification of the eyepiece (ocular lens) by the magnification of the objective lens.

Conclusion

Write your conclusion to the experiment by answering the following questions in your notebook.

1. Explain why some organisms, such as *Euglena* and *Spirogyra*, are green.
2. Compare the movement of unicellular organisms in your samples.
3. You might have seen spaces called vacuoles inside cells in your specimens. What is the function of vacuoles?

Evaluation

Evaluate your practical investigation by considering the following questions.

1. Describe any difficulties you had observing the organisms.
2. How did you overcome these difficulties?
3. Suggest other improvements that could be made to the experiment.

1.14 Modelling cells

Introduction

Most people, including scientists, use drawings or models to represent things, explain ideas, give instructions, send warnings and display emotions. Communication of science ideas can be greatly improved by using clear, accurate and engaging models, including diagrams. The ability to draw diagrams that can describe knowledge or explain understanding is an important part of science inquiry.

In this inquiry activity, you will explore how 2D and 3D models can be used to describe, explain and compare the structure and function of cells, as the teacher is demonstrating in Figure 1.14.1.

Learning intention

To be able to construct and evaluate representations of cells and cell structures

Success criteria

SC 1: I can create and evaluate two-dimensional diagrams to compare plant and animal cells.

SC 2: I can create a three-dimensional model of a plant or animal cell with the organelles accurately represented and labelled.

SC 3: I can evaluate the quality of a three-dimensional model of a cell.



FIGURE 1.14.1 A teacher using a model of a cell to explain parts of a cell

Part A: Drawing cells

Background

An essential skill in science is the ability to effectively communicate observations. While photographic images and videos of cells provide realistic representations, they may not always convey key details without additional information. For example, an image alone may not indicate:

- the actual size of the cell
- its true shape
- internal structures
- whether the cell or its parts are moving.

Providing context and explanations alongside images ensures that observations are accurately understood.

Aims

To draw an accurate and helpful scientific diagram of an animal cell and a plant cell from a micrograph

To provide a written explanation and to use the representations to describe and compare aspects of plant and animal cells

Plan

You will be using an image and description of a plant and animal cell to create a representation.

Your diagrams should include:

- labels of visible cell organelles and structures
- a scale bar
- the magnification
- the use of colours where appropriate.

SkillBuilder

Adding scales to diagrams

GO TO
Toolkit section 2.4, Converting between units

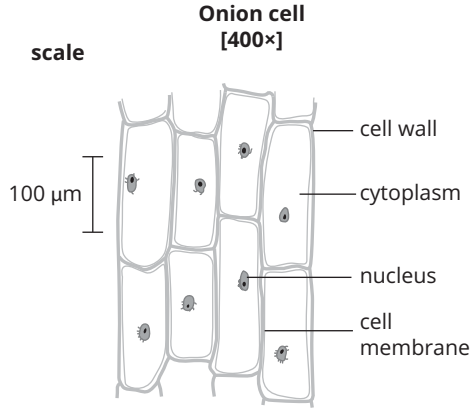
You need to know the magnification of the image to add a scale bar. Scale bars are usually 1 cm long, and the label on the scale bar indicates what distance the 1 cm scale bar represents in terms of the image.

You can divide the distance on the image by the magnification of the image to find out what a scale bar represents.

Example

Paula wanted to calculate what her 1 cm scale bar would represent on an image at a magnification of 40×. She divided 1 cm by 40, which equals 0.025 cm. This is equal to 250 µm. This means that the 1 cm scale bar on Paula's image represents 250 µm in the actual specimen.

Paula then observed some onion cells through a microscope and created the following scientific drawing with a scale bar as shown in the figure. To calculate what the scale bar represents, she divided the distance on the image 1 cm by the magnification (400×), which is 1 ÷ 100 = 0.01 cm, or 100 µm. By using the scale bar, you can see that the length of the onion cells in the actual specimen is approximately 150–200 µm.



Conduct

1 Consider the micrograph of *Elodea* cells (Figure 1.14.2). In your notebook, draw a labelled diagram approximately 4 cm tall that shows the key observable features of this plant cell. Include a scale bar.

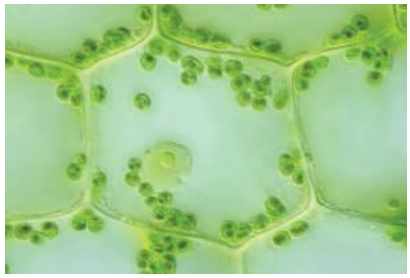


FIGURE 1.14.2 Canadian pondweed, *Elodea canadensis* (darkfield and polarised light micrograph)

HINT

If drawn at a height of 4 cm, the magnification is 1000×.

2 Read the following description of a cell and use your knowledge of cells to create a diagram in your notebook that would communicate the information to a Year 8 student who is also studying this topic.
The animal cell is spherical in shape and contains a nucleus with a clearly visible nucleolus. There are several vacuoles, some close to the edge of the cell where food material is being broken down. Five organelles responsible for producing energy in the cell are visible, and ribosomes can be seen arranged along the internal structure of the cell.

Evaluate

Evaluate your drawing in your notebook by considering the following questions.

1. How was the light micrograph enhanced to communicate more information about the cell?
2. How did your diagram communicate more information than the micrograph?
3. How does your diagram communicate information more effectively than the written description that was given to you?
4. How well do the diagrams differentiate between plant and animal cells?

Part B: Modelling cells

Aims

To create a 3D scientific model of an animal cell or a plant cell from a 2D source

To evaluate how well the model can be used to describe and explain the structure and function of the cell

Plan and design

This activity can be completed as an individual task or as a group activity.

Choose a 2D representation as your source material for your model of a cell. This can be one of the diagrams that you created in Part A of this lesson.

You will be given a range of materials to create the model. The model must meet the following criteria.

- The texture, strength and colour of the materials chosen should best present the cell structures that they represent.
- The model should be made to scale, and the scale should be communicated on the model.
- Structures and organelles should be correctly labelled.
- Where possible, dynamic features or functions of the cell should be represented within the model.
- The model should allow for comparison of the cell represented with other animal or plant cells.

Evaluate

Evaluate your model in your notebook by considering the following questions.

1. How well were you able to select appropriate materials?
2. What was the most challenging aspect of the model to create at the correct scale?
3. What strategies did you use to represent dynamic features of cell function?
4. What additional information about the cell would help you to model the cell more accurately?

1.15 Implications of stem cell research

Learning intention

To be able to explore the ethical and social implications of scientific discoveries such as stem cells

Success criteria

SC 1: I can explain what stem cells are and how they function.

SC 2: I can describe the ethical implications of stem cell research.

SC 3: I can describe the social implications of stem cell research.

Introduction

Stem cells are special cells in the body that can develop into many different types of cells, such as muscle cells, nerve cells or blood cells. This ability to develop into different types of cells makes stem cells a promising tool for treating a variety of medical conditions, from injury or disease of tissues, to diseases that involve the loss or malfunction of cells, such as cancer, heart disease and neurological disorders.

Stem cell research is a field of science that focuses on the study of stem cells and their potential use in medical treatments.

In this inquiry, you will explore the social and ethical implications of stem cell research.

Background

Stem cell research is a rapidly evolving field that has the potential to revolutionise medicine. However, it also raises several social and ethical concerns.

- Social concerns relate to an issue that affects a group of people in society.
- Ethical concerns arise from a person's beliefs about an issue being right or wrong.

Some of the most prominent issues are explained here.

KEY TERM

embryonic stem cell a special cell in the developing embryo (product of a fertilised egg) that can develop into many different types of cells

Embryonic stem cell research

The use of **embryonic stem cells** in research raises ethical questions about the destruction of human embryos.

Some people believe that embryos have moral status and should not be used for research purposes, while others believe that the potential benefits of stem cell research outweigh any moral concerns. 'Moral status' is a term used in ethics to refer to the degree of importance given to something or someone—that is, how important it is to treat them well and make sure no harm is done to them. So, when people say embryos have moral status, they mean that they think embryos are important beings that should be treated with care and respect.

Religious objections

Some religious groups have moral objections to stem cell research. They think it is wrong to conduct stem cell research, particularly when it involves the use of embryonic stem cells. For example, the Roman Catholic Church has stated that the use of embryonic stem cells is morally unacceptable because it involves the destruction of human life.

Access and distribution of treatments

There are concerns about who will have access to stem cell treatments once they become available and who will bear the costs. There are also concerns about how stem cell treatments will be distributed fairly and equitably, especially in developing countries.

Human enhancement

Stem cell research may make it possible to use the technology for purposes beyond therapeutic treatment (use for a disease or illness), such as for human enhancement. This raises ethical questions about what constitutes acceptable uses of the technology and the potential risks and benefits of using it for non-medical purposes.

Privacy and informed consent

The privacy and informed consent of patients who participate in stem cell research, particularly when it comes to the use of their tissue and personal information, is also a source of concern.

Overall, stem cell research is an area of science that requires careful consideration of its social and ethical implications.

Aim

To create an infographic about the scientific discovery of stem cells and the social and ethical implications of stem cell research

Plan

Read the following information on stem cells.

Stem cells

Multicellular organisms, such as humans, are complex beings that are made up of wide variety of cells. Every cell in the body is uniquely structured to carry out a specific function, and this keeps the body working. But how do these cells become so complex and so well suited to each job they perform? The answer comes down to specific stages of development that take place after an egg is fertilised by a sperm and embryonic development begins. During the development of an embryo, clusters of cells, known as embryonic stem cells, start to develop specific characteristics. These stem cells are like a blank canvas that can develop into any type of cell in the body. The stem cell undergoes differentiation and specialisation, where the cell develops specific characteristics that allow the cell to perform its intended function. A gastric chief cell is a specialised cell in the lining of your stomach. It has an unusual shape with finger-like projections coming from the top known as microvilli, a nucleus at the bottom, many mitochondria, and complex structures known as endoplasmic reticulum that allow stomach enzymes to be produced. These stomach enzymes help break down food.

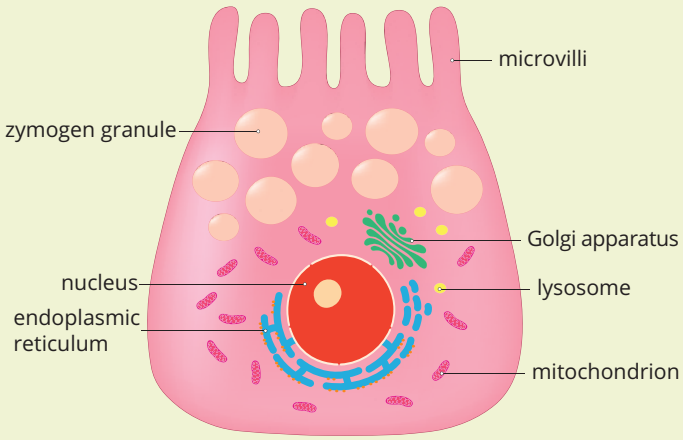


FIGURE 1.15.1 Gastric chief cell structure

The same type of stem cell that produced this gastric chief cell, could have instead developed into a goblet cell that in the lung and responsible for secreting mucus to trap any dust particles that are inhaled.

Embryonic stem cells have an amazing ability to make any type of cell, which is why scientists find them so interesting with their potential possibilities in modern medicine to cure disease and illness. But, with this great potential to repair damaged organs, make new brain cells, and regrow limbs comes great responsibility and debate. Embryonic cells must come from an embryo and how scientists obtain that embryo raises many ethical and social concerns.

Another type of stem cell are adult stem cells that are present in different parts of the body, including bone marrow. These stem cells are already being used in more mainstream medical applications and scientific research. Adult stem cells can develop into a range of cells, but can't develop into every cell type, which makes them more limited in their capacity.

GO TO
Toolkit sections 5.3 Using artificial intelligence (AI) in science writing and 5.4, Graphic organisers: Venn diagrams

1. Using the text provided and further research, make summary notes explaining what stem cells are and how they function.
2. Research the positive and negative social implications of stem cell research. Record these notes in a table.
3. Research the positive and negative ethical implications of stem cell research. Record these notes using a graphic organiser such as a PNI (Positives/Negatives/Interesting) chart or a Venn diagram.

Design

1. Consider what makes an infographic informative and engaging. Take notes about the elements you will use to design your infographic and draft your layout.
2. Using the information gathered in the planning stage of this inquiry activity, consider what information to include in your infographic. Choose your key headings.

Conduct

Using all the information you gathered about stem cell research and infographics, create your infographic. Use the key information you gathered during the Plan stage and the elements and headings that you identified in the Design stage.

Improve

1. State what you are proud of in your infographic.
2. Describe how you can improve the look and feel of your infographic to make it more engaging.
3. Explain how you might change the information to make it more informative.
4. Discuss whether you would do anything differently from the Plan stage next time.

Evaluate

1. What aspect of stem cell research were you investigating in this inquiry activity?
2. In this activity, you planned and conducted an inquiry into stem cell research and the social and ethical implications of this research. What skills did you use during this activity?

1 Cells in plants and animals

Topic summary

The key concepts included in this topic are:

- Cells are the basic unit of all living things and arise from pre-existing cells.
- The evolution of microscopes has allowed people to see cells at a microscopic level and understand more about their specific structure.
- Unicellular organisms can survive as a single cell that undergoes all necessary functions to live independently.
- Multicellular organisms are made up of many different types of cells that work together to allow the organisms to survive.
- All cells have similar features, including cell membranes, genetic material, ribosomes and cytoplasm.
- Plant and animal cells both contain a nucleus and specialised organelles that allow them to survive.
- Plant cells have a cell wall, chloroplast and large vacuole.
- Humans are made up of many different types of specialised cells that are organised into tissues, organs and systems.
- Stem cells are cells that are yet to be specialised and are a topic of ethical consideration in society.

Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

Remember

1 Describe what a cell is.

2 Identify the cell structures that were the first to be observed under a microscope.

3 State a type of cell does not contain a nucleus.

4 Describe the function of the cell membrane.

5 List the key features that a plant cell has that an animal cell does not and briefly describe the function of each feature.

Understand

6 Compare the size of a typical eukaryotic cell (such as plant and animal cells) to prokaryotic cells (such as bacteria).

7 Explain how multicellular organisms differ from unicellular organisms.

8 There are many different types of specialised cells in the respiratory system. What functions would these cells need to carry out?

9 What are scientists able to observe using an electron microscope that they cannot see using a stereo microscope?

10 Why do both plant and animal cells need a nucleus and mitochondria to survive?

Apply

11 How can the cytoplasm be identified in a cell diagram?

12 Calculate the total magnification of a light microscope if the eyepiece magnification is 10× and the objective lens magnification is 40×.

13 Ben is teaching another student how to use the light microscope to identify different parts of onion cells. How could Ben explain to the student how to tell the difference between the cell wall and the cell membrane?

14 An average cheek cell is approximately 60 µm in diameter. Draw a diagram of a cheek cell in your notebook that:

- **a** is 1000 times as large
- **b** includes labelled cell features.

Analyse

15 In an environment where the conditions change quickly, how would the survival of a unicellular organism compare with a multicellular organism?

16 Compare the functions of vacuoles in plant cells and animal cells.

Extension: Research task

17 Research two ways Australian scientists are using stem cells.

- **a** Provide a summary of each of these innovations.
- **b** Outline some ethical and social implications that the scientists would need to consider when conducting their research.

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

body system a group of interconnected organs and tissues that perform functions in the body

cell the building block of all living things

cell membrane a thin layer that separates the cell from its surroundings and controls what can move in and out of the cell

cell theory the idea that all living things are made up of one or more cells that come from pre-existing cells

cell wall a rigid layer on the outside of a plant cell or prokaryotic cell; provides the skeleton of a plant

cellular respiration a set of processes in the cells that converts chemical energy from nutrients into energy (ATP) that can be used by cells

centriole a barrel-shaped structure made from microtubes that is part of the cytoskeleton in animal cells

chlorophyll the substance in plant leaves that makes leaves green and collects energy from the Sun for photosynthesis

chloroplast an organelle within a plant cell where photosynthesis takes place

convex lens a lens that has at least one surface curving outwards

cytoplasm everything contained within a cell membrane except the nucleus

cytoskeleton a network of proteins in the cytoplasm

cytosol fluid in the cytoplasm of a cell

DNA deoxyribonucleic acid, the molecule that contains genetic information for an organism

electron microscope a type of microscope that uses beams of electrons to magnify up to a million times. There are two types of electron microscopes: transmission electron microscopes (TEM) and scanning electron microscopes (SEM)

embryonic stem cell a special cell in the developing embryo (product of a fertilised egg) that can develop into many different types of cells

eukaryotic cell cell that has a nucleus

eyepiece the lens, or combination of lenses, at the viewing end of a microscope or telescope

field of view the amount of the specimen seen through a microscope

lens a piece of glass or other transparent material with curved sides used in optical equipment

light microscope a microscope that uses light to view specimens

lysosome an organelle that gets rid of wastes from animal cells

macroscopic can be seen without the help of a microscope

magnification the ratio of the size of an image to the size of the object

micrograph a photograph of an image from a microscope; also known as a photomicrograph

micrometre one-thousandth of a millimetre, or one-millionth of a metre; the standard unit for micrometre is μm

microscope an instrument used to make very small things look bigger

microscopic can be seen only by using a microscope

mitochondria organelles where energy is released from food through the process of cellular respiration

multicellular made up of many cells

nucleolus an organelle within a cell nucleus that produces ribosomes

nucleus an organelle that contains the genetic information for the cell (plural nuclei)

objective lens the lens in a microscope or telescope that is nearest to the object being viewed

organ a structure that contains at least two different types of tissues that work together to complete a function

organelle a smaller part of a cell in the cytoplasm and having a variety of important functions

organism a living thing that functions as an individual

osmosis the process by which particles of water pass through a semi-permeable membrane from a less concentrated solution into a more concentrated one

photosynthesis the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from sunlight

prokaryotic cell a cell that does not have a nucleus

ribosome an organelle that produces proteins from amino acids; proteins are required for many functions including growth, repair and controlling chemical reactions

semi-permeable membrane a thin layer of material that only certain particles can pass through

specialised cell a cell that has specific structures to allow it to perform specific functions

stereo microscope a binocular microscope that creates a three-dimensional image

tissue a group of cells of the same type that carry out the same function in the body

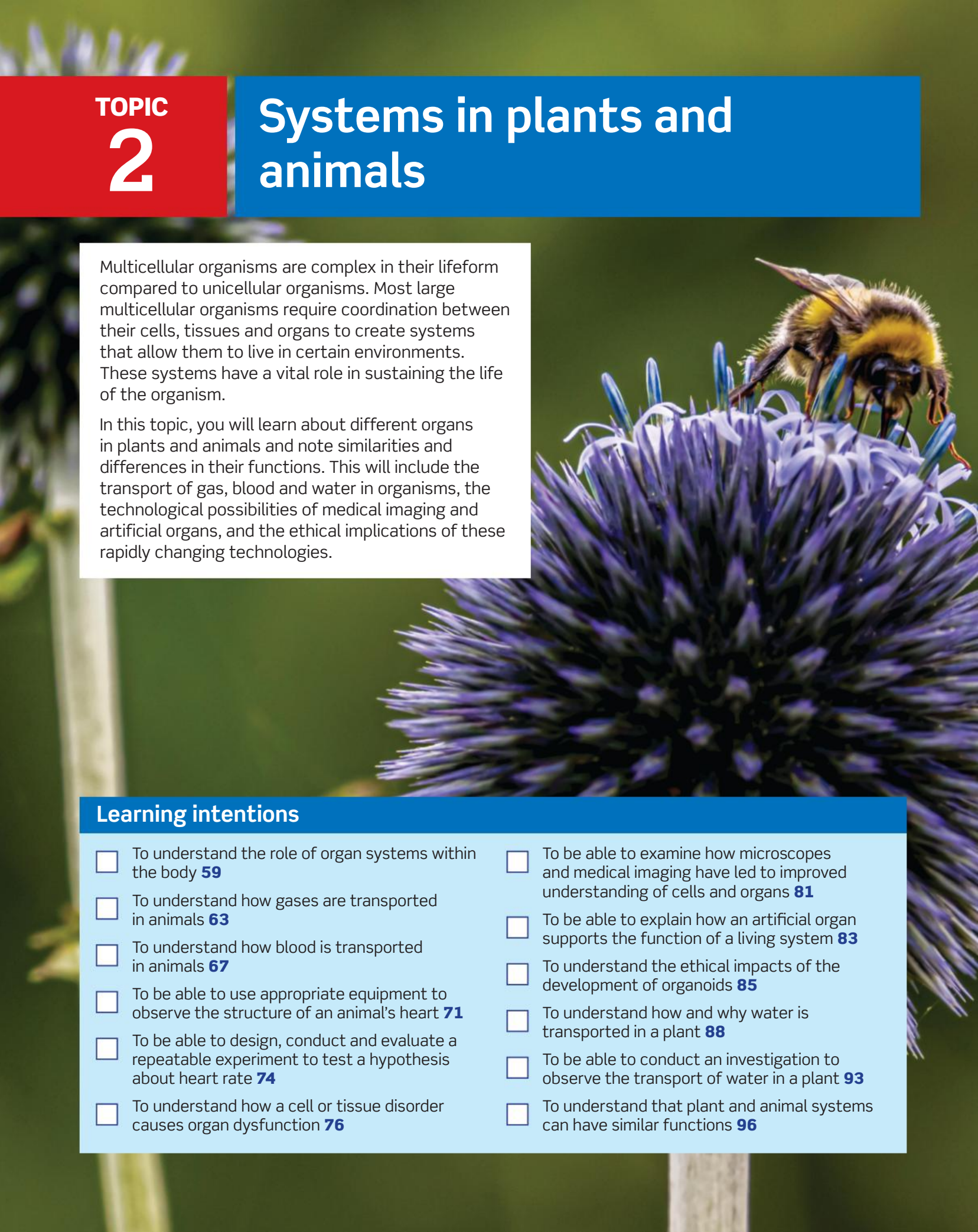
unicellular organism living thing made up of only one cell

vacuole a small structure in animal cells that may contain wastes or chemicals, or a large sap-filled structure in plant cells that stores water, wastes and nutrients



TOPIC 2

Systems in plants and animals



Multicellular organisms are complex in their lifeform compared to unicellular organisms. Most large multicellular organisms require coordination between their cells, tissues and organs to create systems that allow them to live in certain environments. These systems have a vital role in sustaining the life of the organism.

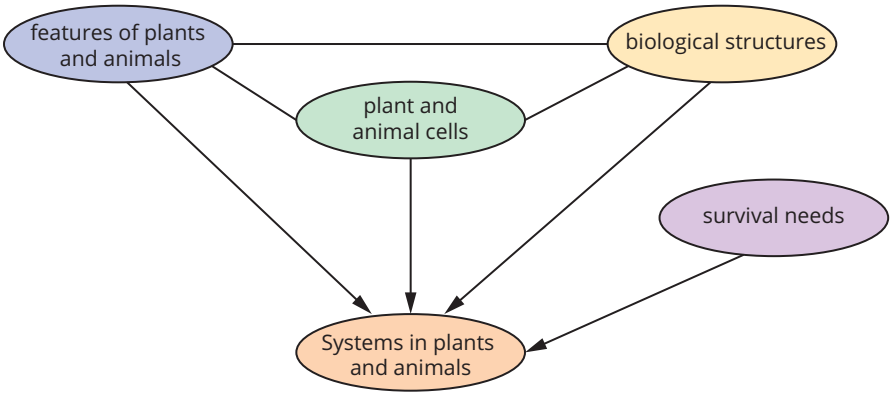
In this topic, you will learn about different organs in plants and animals and note similarities and differences in their functions. This will include the transport of gas, blood and water in organisms, the technological possibilities of medical imaging and artificial organs, and the ethical implications of these rapidly changing technologies.

Learning intentions

- ☐ To understand the role of organ systems within the body **59**
- ☐ To understand how gases are transported in animals **63**
- ☐ To understand how blood is transported in animals **67**
- ☐ To be able to use appropriate equipment to observe the structure of an animal's heart **71**
- ☐ To be able to design, conduct and evaluate a repeatable experiment to test a hypothesis about heart rate **74**
- ☐ To understand how a cell or tissue disorder causes organ dysfunction **76**
- ☐ To be able to examine how microscopes and medical imaging have led to improved understanding of cells and organs **81**
- ☐ To be able to explain how an artificial organ supports the function of a living system **83**
- ☐ To understand the ethical impacts of the development of organoids **85**
- ☐ To understand how and why water is transported in a plant **88**
- ☐ To be able to conduct an investigation to observe the transport of water in a plant **93**
- ☐ To understand that plant and animal systems can have similar functions **96**

2 Systems in plants and animals

The key concepts that you will use in this topic:

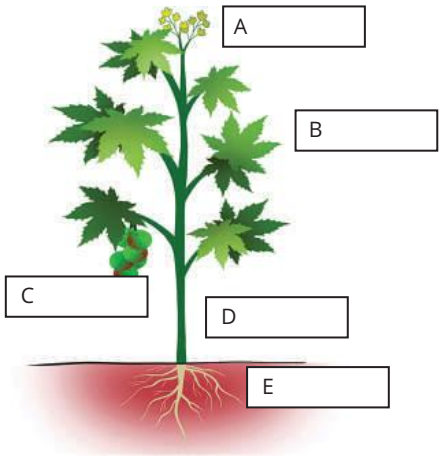


The following prior knowledge questions will help to support your learning in the topic and can be attempted before the first lesson.

Specialised cells and tissues

1 Identify two different systems of the human body.

2 Identify each structure of the plant labelled A–E in the picture below.



3 Explain how brightly coloured flowers attract pollinators such as honeybees.

Gas exchange and transport

4 Describe how the lungs help in the process of breathing.

5 Compare the processes by which plants and animals take in water.

Organ structure

6 Describe the function of the heart in the circulatory system.

2.1 Cells, tissues and organ systems

Lesson overview

Cells carry out all the necessary functions for an organism to survive and reproduce. Unicellular organisms that are made up of only one cell can perform all the functions they need to stay alive. Multicellular organisms, such as humans, birds (Figure 2.1.1), insects, flowering plants and ferns, have specialised cells that group to form tissues. These tissue groups are specialised and form organs that have important functions. For example, some organs enable the organism to obtain nutrients and water, and others enable those substances to be circulated throughout the body and to the cells. Systems consist of organs that work together to keep an organism functioning.

In this lesson, you will learn about the roles of the systems that work together to keep an organism alive.

SC 1 I can explain how cells and tissues make up organs

Learning intention

To understand the role of organ systems within the body

Success criteria

SC 1: I can explain how cells and tissues make up organs.

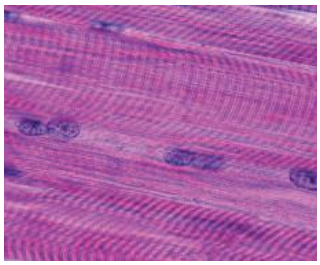
SC 2: I can describe the main functions of the respiratory, circulatory, excretory and digestive systems.

SC 3: I can explain how major organs contribute to the functions of the respiratory, circulatory, excretory and digestive systems.

Specialised cells

Organisms that are **multicellular** can have many **cells** making up the structures that enable the organism to function. They do all the work required for the body to stay alive. They need nutrients, oxygen and water to be able to function. **Specialised cells** are cells that have specific functions. Their shapes, sizes and organelles vary depending on their function (Table 2.1.1). For example, nerve cells in the brain are long and have multiple extensions. Muscle cells tend to be elongated and fat cells are large and round.

TABLE 2.1.1 Specialised cells of the human body

Specialised cell		Structure and function
Skeletal muscle cell		Skeletal muscle cells that are attached to bones via tendons have striations or stripes and contract to move bones for body movement.
Red blood cell		Red blood cells have a specific shape that is flexible enough to allow them to transport oxygen while also allowing them to squeeze through blood vessels in single file.

continued

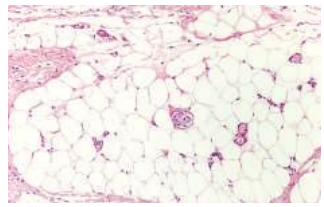
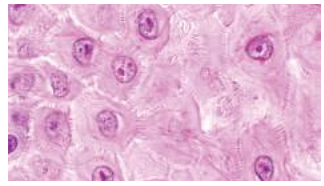


FIGURE 2.1.1 An Australian king parrot and the wattle tree it is perched in are both multicellular organisms.

KEY TERMS

multicellular made up of many cells
cell the building block of all living things
specialised cell a cell that has specific structures to allow it to perform specific functions

TABLE 2.1.1 *Continued*

Specialised cell		Structure and function
Nerve cell		Nerve cells can conduct electric currents along their long branching extensions to other cells or tissue.
White fat cell		The structure of white fat cells allows large amounts of energy to be stored for the body.
Skin cell		Skin cells are tough and waterproof. They form a layer of protection for the body.

Tissues to organs

KEY TERMS

tissue a group of cells of the same type that carry out the same function in the body

organ a structure made up of at least two different types of tissues that work together to complete a function

Tissues are a group of specialised cells that work together and have specific functions. For example, muscle tissue in your arms and legs can contract and enables your bones to move. Plants have tissue that is specialised to transport water from the roots through the stems and to the leaves.

Organs are groups of tissues that work together to perform a specific function. For example, some parts of the heart are made of a type of muscle tissue called cardiac muscle. A different type of tissue covers the exterior of the heart. Another example is shown in Figure 2.1.2 and Figure 2.1.3 and is where bone tissue makes up bones.

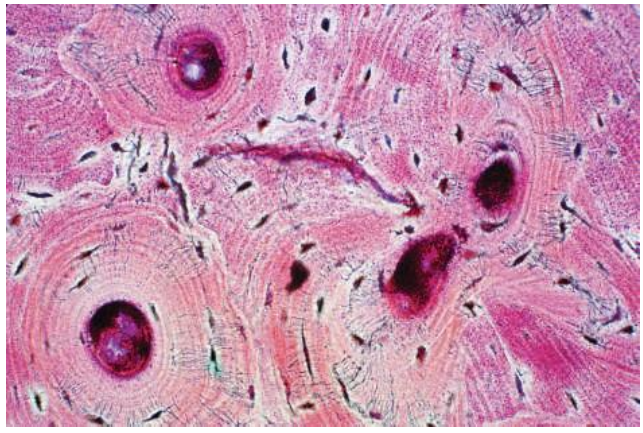


FIGURE 2.1.2 Bone tissue is structured in concentric rings to provide strength and rigidity.



FIGURE 2.1.3 Bone tissue makes up bones.

SC 1 CHECK YOUR UNDERSTANDING

Describe what tissue is made up of.

SC 2 I can describe the main functions of the respiratory, circulatory, excretory and digestive systems

KEY TERM

organ system two or more different organs working together

Multicellular organisms must have efficient ways of obtaining oxygen, food and water, getting rid of wastes and transporting all substances around the body. **Organ systems** are made of organs that work together to perform a specific task. Each system has a role to play in keeping the organism alive. For example, the heart and blood vessels take essential substances to the tissues in the body and take away the waste substances that the cells produce. There are many organ systems that allow the human body to function. Some examples of systems include the reproductive system, nervous system and the digestive system.

The respiratory system

The **respiratory system** gets oxygen from the air when breathing in and removes the waste gas (carbon dioxide) when breathing out (Figure 2.1.4). Oxygen is essential for the body's functioning.



FIGURE 2.1.4 The respiratory system takes oxygen from air and releases carbon dioxide back into the air.

The circulatory system

The **circulatory system** (Figure 2.1.5) is responsible for transporting substances to and from cells, such as oxygen, carbon dioxide and glucose. It is composed of the heart, blood vessels and blood.

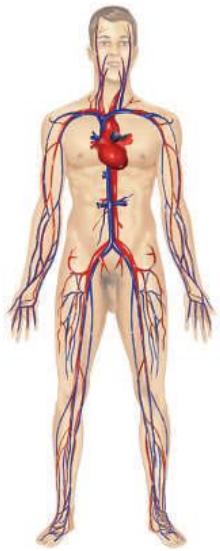


FIGURE 2.1.5 The circulatory system transports substances such as nutrients and oxygen throughout the body to all the cells.

The digestive system

The **digestive system** (Figure 2.1.6) breaks down and absorbs food and nutrients and consists of organs such as the stomach, small intestine and large intestine. Food that is taken into the body must be broken down, or digested, into smaller particles and molecules so the cells can use the nutrients.

The excretory system

The **excretory system** (Figure 2.1.7) removes waste from the cells that would otherwise be toxic and could cause cell death. The main organs involved in the excretory system are the kidneys and bladder.

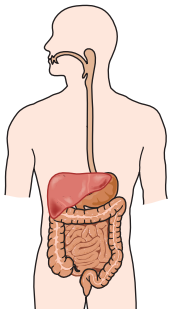


FIGURE 2.1.6 The digestive system breaks down food into molecules that can be transported to the cells for their use.

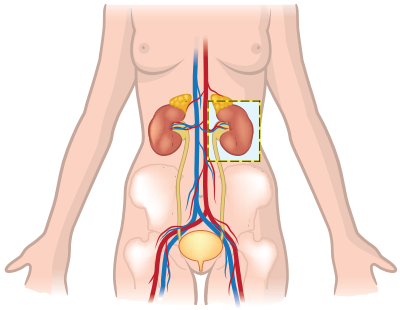


FIGURE 2.1.7 The excretory system removes wastes from the body through the kidneys such as urine and other toxins.

SC 2 CHECK YOUR UNDERSTANDING

Identify the main function of the respiratory system.

SC 3 I can explain how major organs contribute to the functions of the respiratory, circulatory, excretory and digestive systems

Each body system is made up of several organs and other structures that are vital to their overall functions (Table 2.1.2).

TABLE 2.1.2 Major organs in body systems

The respiratory system

The respiratory system has many structures that contribute to its function, including the mouth, nose, trachea and lungs.

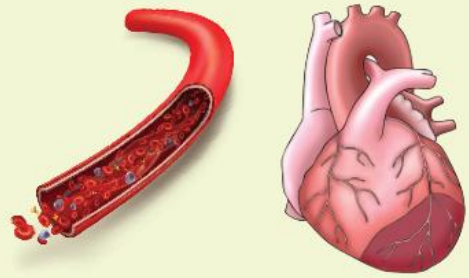
The lungs are made of millions of tiny air sacs that allow oxygen to be taken from the air and delivered to the blood. Carbon dioxide is breathed out of the lungs.



The circulatory system

The circulatory system contains vessels to transport blood.

The heart is the major organ of the circulatory system, and it pumps blood.



The digestive system

The digestive system needs many organs to break down and process food, including the mouth, oesophagus, stomach and intestines.

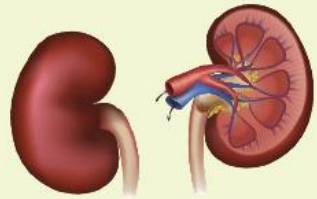
After crushed food is swallowed, the oesophagus pushes it down into the stomach where it is digested further.



The excretory system

The excretory system has several major organs, including the kidneys and bladder.

The kidneys filter blood like a swimming pool filter filters pool water, and the wastes are eventually removed from the bladder in urination.



SC 3 CHECK YOUR UNDERSTANDING

Identify the major organ responsible for pumping blood in the circulatory system.

Lesson review

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

1. Identify the basic building blocks of organs in the human body.
2. Explain how cells and tissues make up the structure of organs.
3. Name four main organ systems.
4. Describe how the digestive system and circulatory system work together to nourish the body.
5. Compare the roles of the circulatory and respiratory systems.

2.2 Gas transport

Lesson overview

The oxygen in the air that you breathe is essential for life and it needs to be transported to cells all around the body.

The respiratory system is responsible for providing the oxygen that all cells need. Cells must have oxygen to undergo a process called cellular respiration. Cellular respiration is a chemical reaction in which oxygen reacts with glucose to produce energy for all cell functions. Cellular respiration also produces carbon dioxide as a waste product. The respiratory system rids the body of this toxic waste.

In this lesson, you will learn about the role of the respiratory system and the structures that move air into and out of the lungs when you breathe.

SC 1	I can identify and describe the role of the trachea, bronchi, bronchioles and alveoli in the structure of a lung

The main function of the respiratory system (Figure 2.2.1) is to deliver **oxygen** to the bloodstream. It does this by taking air in through the mouth and nose, delivering it to the **lungs** and then into the blood. Oxygen is essential for **cellular respiration** and the functioning of the body.

You can learn more about the structure of each part of the respiratory system in Figure 2.2.1.

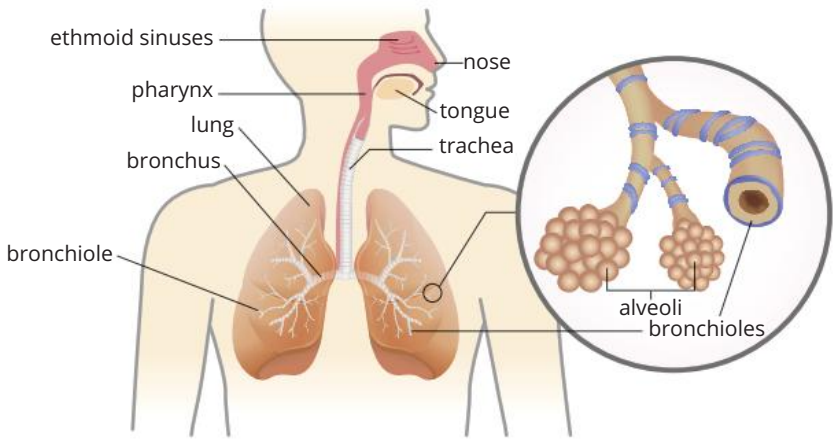


FIGURE 2.2.1 The respiratory system is made up of a series of tubes and air sacs.

Structures and functions of the respiratory system

Nasal cavity

The **nasal cavity** is an air-filled space behind the nose that connects the nose to the pharynx, the cavity at the back of the nose (Figure 2.2.1). The air is warmed by the body, and the nasal cavity is lined with tiny hairs and mucus that trap dust and foreign particles to prevent them from entering the airway.

Learning intention

To understand how gases are transported in animals

Success criteria

SC 1: I can identify and describe the role of the trachea, bronchi, bronchioles and alveoli in the structure of a lung.

SC 2: I can explain the mechanism of inhalation and exhalation of air.

SC 3: I can compare respiratory systems in a range of terrestrial and aquatic animals.

KEY TERMS

oxygen a gas that animals, including humans, breathe in from the air and use to help their bodies produce energy

lung an organ in the chest cavity where gas exchange occurs

cellular respiration a set of processes in cells that converts chemical energy from nutrients into energy (ATP) that can be used by cells

nasal cavity the hollow space inside the nose that air passes through when breathing, helping to filter, warm and moisten the air before it reaches the lungs

KEY TERMS

trachea the tube that carries air from the nose and mouth into the chest cavity
bronchi tubes formed by the division of the trachea
bronchiole small tubes formed by the division of the bronchi
alveoli tiny air sacs in the lungs where oxygen from the inhaled air enters the bloodstream and where carbon dioxide from the bloodstream is released into the exhaled air

Trachea

The **trachea** is also known as the windpipe. It is a strong but flexible tube that has tiny hairs to trap dust. Air travels down this pipe from the pharynx to the bronchi (Figure 2.2.1).

Bronchi and bronchioles

The **bronchi** (singular: **bronchus**) are smaller tube-like structures that split into two sides. This is where you would commonly see the left and right lung in a diagram. The tubes of the bronchi get smaller and smaller until they form **bronchioles**.

The trachea is like the trunk of a tree that then has branches (the bronchi), which then go into stems (the bronchioles) (Figure 2.2.2).

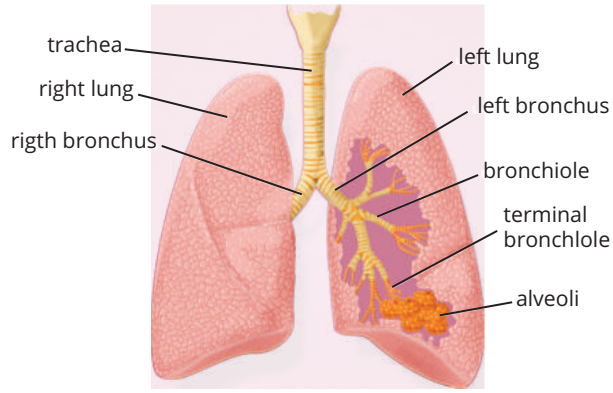


FIGURE 2.2.2 Bronchioles in the lungs

Alveoli

At the end of the bronchioles are microscopic bunches of air sacs known as **alveoli**. This is where the air reaches the bloodstream. Alveoli are covered with blood vessels, and gases are pushed into the bloodstream (Figure 2.2.3).

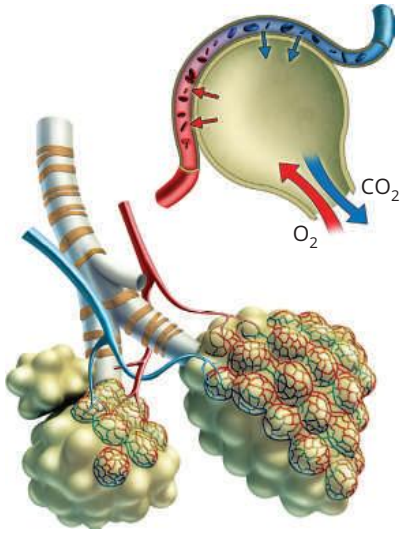


FIGURE 2.2.3 Alveoli structure and function. Red arrows show oxygenated air that is moving into the alveoli and the bloodstream. Blue arrows show gases that are being breathed out of the alveoli.

SC 1 CHECK YOUR UNDERSTANDING

Explain how the bronchi and bronchioles allow air to move further into the lungs.

SC 2 I can explain the mechanism of inhalation and exhalation of air

KEY TERM

diaphragm a sheet of muscle that separates the chest from the abdomen

The ribs and the lungs

The ribcage surrounds the lungs and protects them. Muscles in between the ribs are known as intercostal muscles. They assist with raising the ribcage up and down when breathing in and out. The **diaphragm** is a muscle that separates the lungs from the abdomen and works by contracting to increase volume in the chest cavity when breathing in.

Breathing

Breathing involves air moving in and out of the lungs. This allows for a constant supply of oxygen-rich air to enter the alveoli and for the removal of **carbon dioxide** from the blood.

KEY TERM

carbon dioxide a gas that animals, including humans, exhale when they breathe out, produced as a result of their body's metabolic processes; also used by plants in photosynthesis

Inhalation (breathing in) is the process of air moving into the lungs (Figure 2.2.4a). This occurs when the diaphragm and intercostal muscles contract, which moves the ribcage up and outwards. The diaphragm flattens. The volume of the chest cavity increases, which decreases the air pressure in the lungs, causing air to move into the lungs.

Exhalation (breathing out) is the process of moving air out of the lungs (Figure 2.2.4b). The diaphragm and the intercostal muscles relax, and this moves the diaphragm up and the ribcage down and inwards. The volume of the chest cavity decreases, which increases the air pressure in the lungs, causing air to move out of the lungs.

Breathing is an involuntary process; it occurs without thinking about it. However, breathing can be controlled voluntarily for tasks such as speaking, singing or holding your breath underwater.

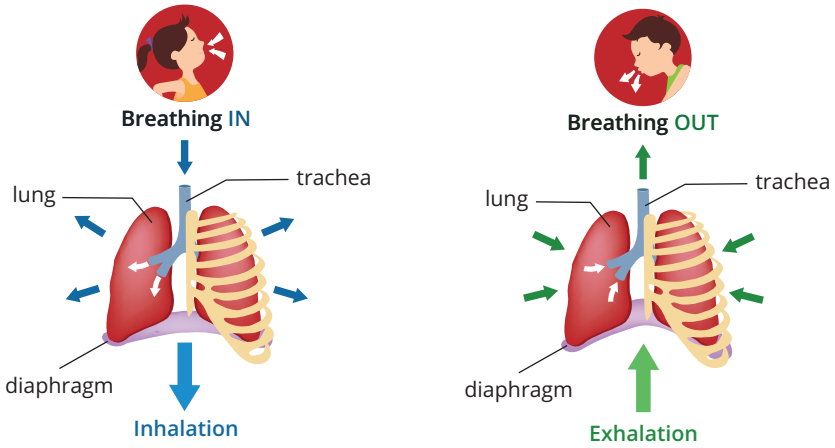


FIGURE 2.2.4 (a) Inhalation is the process of air moving into the lungs. (b) Exhalation is the process of air moving out of the lungs.

SC 2 CHECK YOUR UNDERSTANDING

Explain how the diaphragm and intercostal ribcage muscles work together during inhalation.

SC 3 I can compare respiratory systems in a range of terrestrial and aquatic animals

Animals have many ways of obtaining oxygen and releasing carbon dioxide. Large terrestrial animals (those who live on land) have lungs, whereas most aquatic animals (those who live in water) have **gills**.

KEY TERM

gill a specialised respiratory organ in aquatic animals such as fish that extracts oxygen from water and releasing carbon dioxide

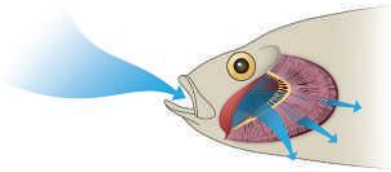


FIGURE 2.2.5 Fish have gills for gas exchange.

KEY TERM

capillary the narrowest type of blood vessel; capillaries reach nearly every cell of the body

Fish have gills just behind the head on both sides (Figure 2.2.5). They have thousands of **capillaries** (small blood vessels) that increase the surface area for gas exchange. Oxygen is dissolved in the water and is absorbed by the gills, whereas carbon dioxide is released into the water.

Frogs and other amphibians have lungs, but they also exchange gases across the surface of their skin (Figure 2.2.6). The skin is very moist so that oxygen can be absorbed from the air and water. Compared to other animals, the lungs of amphibians are quite basic in structure, and that is why they also rely on the exchange of carbon dioxide and oxygen on their wet skin.

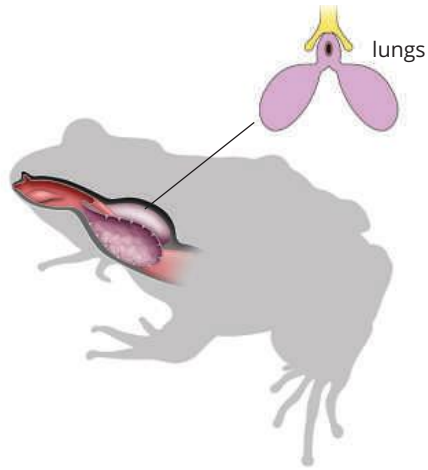


FIGURE 2.2.6 Amphibians such as frogs have lungs, but they also have moist skin that allows oxygen to be absorbed.

Reptiles have scaly skin that prevents any oxygen from being absorbed through the skin. They breathe through lungs as do birds and mammals. The large surface area of the alveoli allows for efficient gas exchange.

SC 3 CHECK YOUR UNDERSTANDING

Explain how the respiratory system of a mammal differs from that of a fish.

Lesson review

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

1. Identify the four main structures involved in the passage of air in the lungs.
2. Name one terrestrial animal and one aquatic animal with distinct respiratory systems.
3. Explain the role of the alveoli in the respiratory system.
4. Describe the movement of the diaphragm during the process of exhalation.
5. Compare the gas exchange process of a mammal and a frog.

2.3 Transport of blood

Lesson overview

The movement of blood around the body is essential for health and survival. When you cut your skin, you can see blood flow out from the wound.

All cities have transport systems to enable people to get from one place to another. Cars and buses travel on roads to get around the city. Transport systems get people to work, to the shops and sport centres, to home and then back again. The circulatory system (Figure 2.3.1) is a transport system that moves blood from a central pump, the heart, through tubes called blood vessels. In the example of the city transport system, you can think of the city as the central point—the heart; the roads are the blood vessels; the cars and buses are the blood; and the shops, sports centres and home are the tissues and organs relying on the transport system.

In this lesson, you will explore the circulatory system's role in maintaining an organism's life by transporting blood and the nutrients it carries.

SC 1 I can describe the structure and function of the heart in the circulatory system

Learning intention

To understand how blood is transported in animals

Success criteria

SC 1: I can describe the structure and function of the heart in the circulatory system.

SC 2: I can explain the movement of blood through the circulatory system.

SC 3: I can compare circulatory systems in a range of terrestrial and aquatic animals.

The flow of blood in the body

The circulatory system has many functions. Oxygen and nutrients are transported to cells and wastes are removed.

In humans, the heart is a four-chambered organ that pumps blood from the body to the lungs, and then from the lungs to the body (Figure 2.3.1). The blood that returns from the body has less oxygen in it because the oxygen has been used by cells throughout the body for cellular respiration. This blood is referred to as deoxygenated blood. The blood then picks up oxygen as it moves through the lungs. This now oxygenated blood (blood enriched with oxygen) moves to the heart and is pumped around the body (Figure 2.3.2).

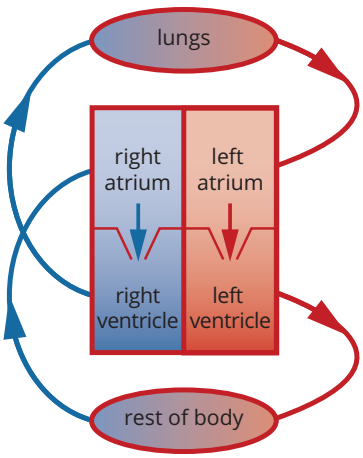


FIGURE 2.3.1 This is a simplified graphic showing the flow of blood through the chambers of the heart.

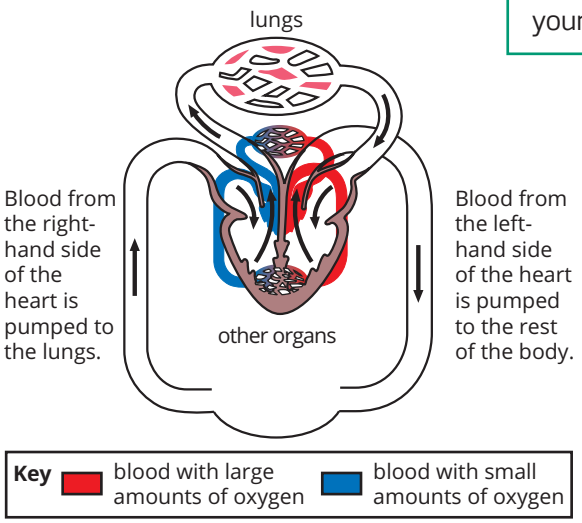


FIGURE 2.3.2 Blood flow to and from the heart

Scifile

Blood vessels length

If you laid out all the blood vessels in your body end to end, they would stretch about 100 000 kilometres. That's enough to circle Earth more than twice! These vessels transport blood to every part of your body.

How the heart works

KEY TERMS

atria the upper chambers of the heart that take blood into the heart
ventricle one of the lower chambers of the heart that pump blood to the body or lungs
vena cava the large vein that carries deoxygenated blood from the body to the heart
pulmonary vein a vein that brings oxygenated blood from the lungs to the heart
valve a structure in the heart and blood vessels that controls the direction of blood flow, preventing backflow
pulmonary artery an artery that carries deoxygenated blood from the heart to the lungs
aorta the largest artery in the body, carrying oxygenated blood from the heart to the rest of the body

The heart is made of cardiac muscle tissue. This special type of muscle does not get tired like the skeletal muscles; it continuously contracts an average of 72 times per minute. The heart has four chambers: two small chambers, the right and left **atria** (singular: **atrium**), and two larger chambers, the right and left **ventricles**. The right and left sides are kept separate by a thick wall of muscle.

The right atrium receives blood from the body through a large vein called the **vena cava**, and the left atrium receives blood from the lungs through the **pulmonary veins**. Once the atria fill with blood, it is pumped to the ventricles through **valves**. These valves prevent the blood from flowing back into the atria. Once the ventricles have filled with blood, the heart muscle contracts and pumps the blood through arteries. The right ventricle pumps blood to the lungs via the **pulmonary arteries**, and the left ventricle pumps blood to the body via the biggest artery in the body, the **aorta**. There are valves between the ventricles and the arteries to prevent blood flowing back into the ventricles (Figure 2.3.3).

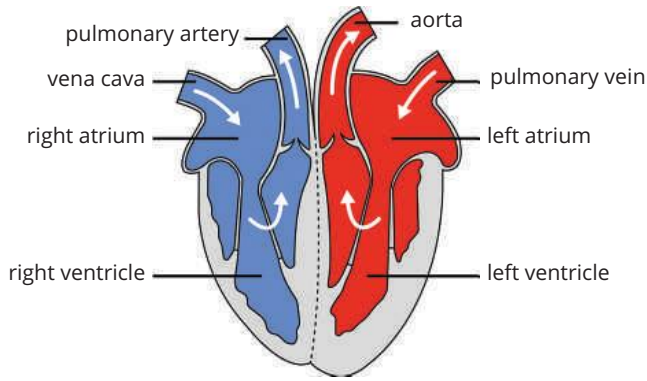


FIGURE 2.3.3 Anatomy of the heart

SC 1 CHECK YOUR UNDERSTANDING

Identify the names of the four different chambers of the heart.

SC 2 I can explain the movement of blood through the circulatory system

KEY TERMS

plasma the clear yellowish liquid part of blood that carries blood cells and other substances such as nutrients and wastes
platelet a small cell fragment in blood that helps with clotting to prevent excessive bleeding when there is an injury
red blood cell a cell that carries oxygen from the lungs around the body
artery a blood vessel that carries blood away from the heart to different parts of the body

Blood consists of a clear yellowy liquid called **plasma**, blood cells and cell fragments called **platelets**. It also carries substances such as nutrients and wastes that are dissolved in the plasma (Figure 2.3.4). **Red blood cells** carry oxygen from the lungs to every cell in the body.

The blood is carried to various parts of the body through a system of blood vessels. There are three main types of blood vessels.

- **Arteries** carry blood away from the heart to other areas of the body. They have thick muscular walls and are under high pressure from the heart to help push the blood along, even to the farthest parts of the body.

- **Veins** carry blood towards the heart from other areas of the body. They are less muscular than arteries because they are under less pressure than the arteries. Most veins must carry blood back to the heart against gravity as blood moves from the feet to the heart. They contain valves to help prevent backflow of blood.
- Capillaries are microscopic and are only one cell thick. They have a very thin wall that surrounds them, and this allows substances in the blood to pass through (Figure 2.3.5). Capillaries lie between the arteries and veins and carry blood through the tissues to deliver oxygen, glucose and other nutrients to the cells. They also carry wastes away from the cells throughout the body.

KEY TERM

vein a blood vessel that carries blood to the heart

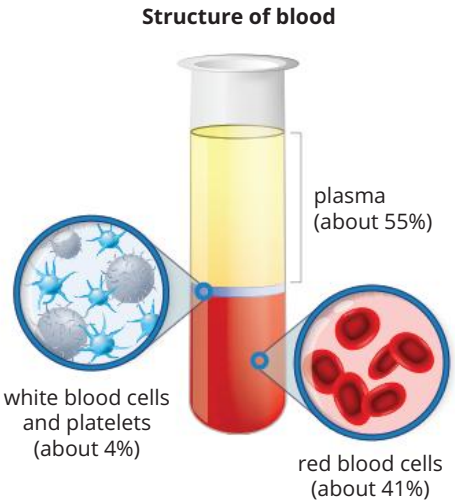


FIGURE 2.3.4 The components of blood

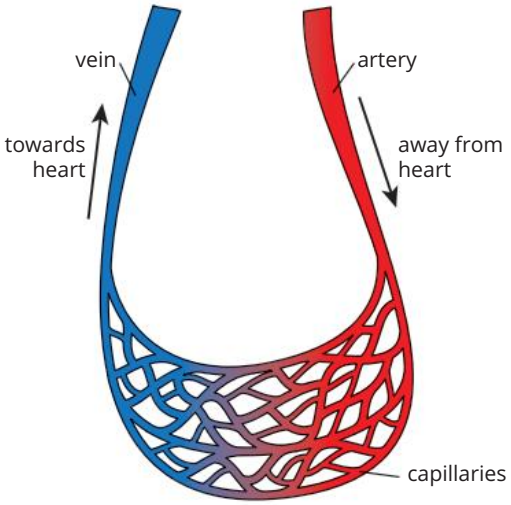


FIGURE 2.3.5 How blood vessels, arteries and veins connect via the capillaries, and the direction of blood flow to and from the heart

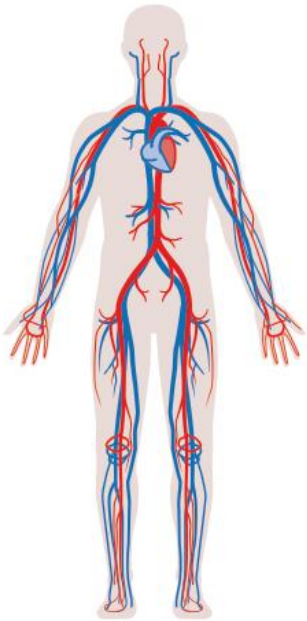


FIGURE 2.3.6 The circulatory system contains the heart and blood vessels.

SC 2 CHECK YOUR UNDERSTANDING

Explain how veins differ from arteries in structure and function.

SC 3 I can compare circulatory systems in a range of terrestrial and aquatic animals

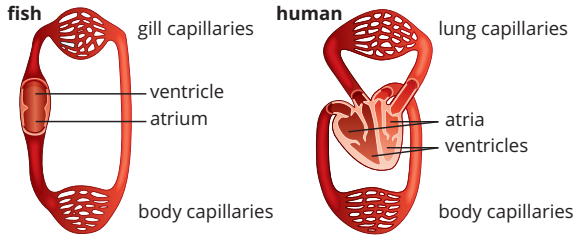
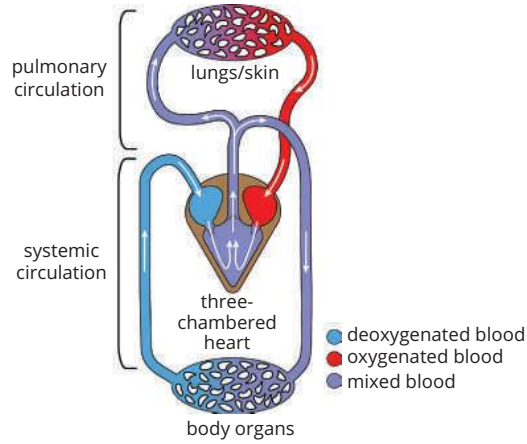
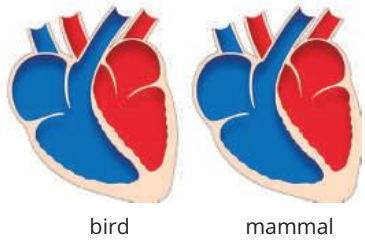
There are many differences between the circulatory systems of terrestrial and aquatic animals (Table 2.3.1). All vertebrates (animals with a backbone) have **closed circulatory systems**, in which the blood vessels that transport blood form a circuit that begins and ends at the heart. Some animals have **open circulatory systems** in which blood is not enclosed in blood vessels and is in direct contact with the tissues of the organism. This occurs in most invertebrates (animals without a backbone) such as insects, crabs and snails.

KEY TERMS

closed circulatory system a circulatory system in which blood is enclosed in vessels and circulates through a complete circuit, starting and ending at the heart

open circulatory system a circulatory system in which blood is not fully enclosed in vessels and directly bathes tissues; common in invertebrates

TABLE 2.3.1 Circulatory systems in terrestrial and aquatic animals

Fish		Fish have a very simple circulatory system that is a single circuit with a two-chambered heart. The single atrium receives blood from the body and the single ventricle pumps the blood to the gills for reoxygenation.
Amphibians		Just like humans, frogs and other amphibians have closed circulatory systems with a few blood vessels, but they only have a three-chambered heart. The heart has two atria and only one ventricle. Reptiles are similar, although the ventricle is partially divided to prevent too much mixing of oxygenated and deoxygenated blood.
Birds and mammals		Birds and mammals, such as humans, have four-chambered hearts. The heart has two atria and two ventricles. The right ventricle pumps blood to the lungs and the left ventricle pumps blood to the body. This is called a closed double-circulation circuit.

SC 3 CHECK YOUR UNDERSTANDING

Explain how the circulatory system of a mammal differs from that of a fish.

Lesson review

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

1. Identify the main components of blood.
2. Name the two main types of blood vessels.
3. Compare the functions of the atria and ventricles in the heart.
4. Describe how blood moves from the heart to the rest of the body and back.
5. Compare open and closed circulatory systems.

2.4 Structure and functions of the heart

Introduction

In humans, the heart is a four-chambered organ that pumps blood from the body to the lungs, and then from the lungs to the body. The heart is made of cardiac muscle. In an average lifespan, a human heart will beat more than 2.5 billion times.

In this practical investigation, you will explore the structure and function of a heart by dissecting a sheep's heart (Figure 2.4.1).



FIGURE 2.4.1 Students dissecting a sheep heart

Learning intention

To be able to use appropriate equipment to observe the structure of an animal's heart

Success criteria

SC 1: I can describe, using observation, the flow of blood through the left and right chambers of the heart.

SC 2: I can draw a labelled diagram to describe the actions of the components of the heart.

SC 3: I can analyse the ethical issues about the use of dissections to learn about living things.

Background

The blood that returns from the body to the lungs has less oxygen in it because the oxygen has been used by the cells in the body for cellular respiration.

The heart has four chambers: two small chambers, the right and left atria; and two larger chambers, the right and left ventricles. The right and left sides are kept separate by a thick wall of muscle.

The heart that you will investigate has a similar structure to a human heart.

Aim

To investigate the structure of the heart and to link components of the heart to their functions

SAFETY NOTES

- Take care with sharp instruments.
- Wear disposable gloves and safety glasses when handling the heart.
- Wash your hands thoroughly after you have completed the dissection.
- Dispose of all materials as directed by your teacher. Do not place any material in normal rubbish bins.

Materials

- sheep heart
- scalpel
- forceps
- blunt probe
- disposable gloves
- dissection board
- safety glasses

Assessment of risk

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

Method

Before you start the experiment, read the questions in the conclusion. During the dissection, make any notes in your notebook. You may need these notes to answer these questions.

1 Position the heart for observation on the dissecting board as illustrated in Figure 2.4.2.

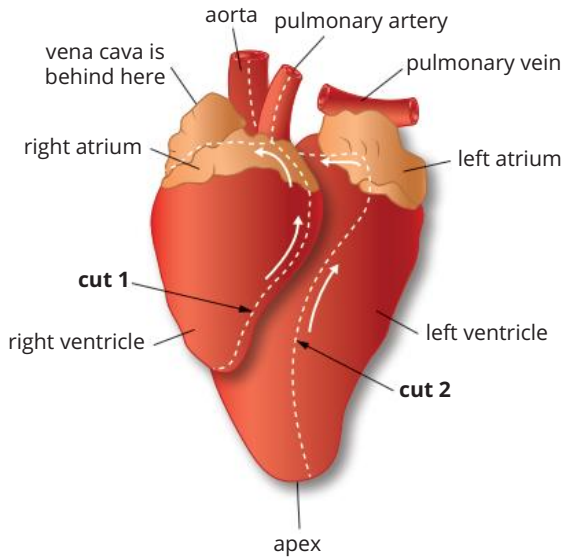


FIGURE 2.4.2 A diagram of a heart

GO TO
Toolkit section 2.1, Reducing risk

2 Identify and label the external features of the heart, including the right and left atria, right and left ventricles, aorta, vena cava, pulmonary arteries and veins.

3 Apply light pressure to the heart using the palm of your hand, mimicking a slight squeezing motion.

4 Use the blunt probe to explore the entry and exit points of blood vessels within the heart chambers. Employ the scalpel to create cut 1, following the diagram's guidance. Ensure that the blade is directed upwards and away from you. See Hint.

HINT

A blunt probe is very useful to identify blood vessels. Pass the probe through the vessel into a heart chamber.

5 Observe the thickness of the right ventricle wall.

6 Gently spread open the right ventricle to reveal its internal structures.

7 Study the thread-like tendons and associated flap-like valves, observing their connections and positions.

8 Analyse and understand how the valves regulate the flow of blood.

9 Observe the flaps at the base of the pulmonary artery, identified as semilunar valves.

10 Create cut 2 to expose the left ventricle and continue the incision upwards into the aorta.

11 Observe and compare the thickness of the left ventricle wall to the thickness of the right ventricle wall.

12 Locate the semilunar valve position at the end of the aorta.

13 Just above the semilunar valves, identify two small openings that represent the branches of the coronary arteries. Use the probe to trace the path of these branches.

Results

Record notes from your experiment.

Conclusion

1 How hard was it to compress the heart, and what does this say about the tissues that make up the heart?

2 Compare and explain the thickness and texture of the aorta and vena cava.

3 Compare the thickness of the walls of the right and left ventricles and propose a reason for the difference.

4 Describe the purpose of the coronary arteries.

5 Construct a simplified diagram of the heart as a pumping system and use arrows to show the path of blood flow through the heart.

Evaluation

Describe at least one **ethical** issue with using dissections to learn about living things, and suggest at least one way to address any ethical concerns.

KEY TERM

ethics a set of principles by which your actions can be judged morally acceptable or unacceptable

2.5 Investigating heart rate

Learning intention

To be able to design, conduct and evaluate a repeatable experiment to test a hypothesis about heart rate

Success criteria

SC 1: I can design a method for a reproducible investigation to test a hypothesis about heart rate and exercise.

SC 2: I can conduct a valid investigation by controlling variables.

SC 3: I can evaluate the validity of the results and conclusions from an investigation.

KEY TERM

pulse the regular expansion and contraction of the arteries in response to the heartbeat



FIGURE 2.5.1 Measuring pulse at the carotid artery



FIGURE 2.5.2 Heart rate data from an app connected to a sports watch

Introduction

One of the roles of blood is to transport oxygen around the body. This oxygen is used in muscle cells to release energy for the muscles to use. The more energy required, the more oxygen is needed; therefore, the flow of blood around the body will be affected.

In this practical investigation, you will investigate how exercise affects heart rate.

Background

Aerobic exercise, or 'cardio', means 'with oxygen'. It includes activities such as fast walking, jogging, swimming and cycling.

Anaerobic exercise is fuelled by stored muscle energy. It includes intense activities such as sprinting, jumping and weightlifting.

During exercise, your muscles need more oxygen, so your heart rate increases to pump blood around your body faster. The effect on heart activity during exercise can be monitored by measuring the **pulse**, which is normally measured as heart beats per minute. Heart rate can be measured by feeling the pulse of the radial artery in the wrist or the carotid artery in the neck (Figure 2.5.1).

Many sports watches are also able to give an instant reading of heart rate (Figure 2.5.2).

Aim

To investigate the effect of exercise on heart rate

Hypothesis

You can decide which aspect of exercise you want to investigate. You can choose one of the following questions to investigate or construct one of your own.

- How much does heart rate change after exercise?
- How long after exercise does it take to return to the resting heart rate?
- Does the speed of running affect the change in heart rate?
- What techniques can be used to reduce the increase in heart rate while exercising?
- What techniques can be used to return to a resting heart rate after exercise?
- Which has a greater effect on heart rate—push-ups or pull-ups?

Once you have identified a question, write a hypothesis for your investigation.

Prediction

Write a prediction for your investigation.

Method

Write a method for your investigation to test your prediction. Make sure that you include ways to ensure that your experiment is valid.

GO TO
Toolkit sections 1.2, Making predictions from observations and 2.6, Reducing error and improving accuracy

Materials

Write a materials list for your investigation.

SAFETY NOTES

- Write safety notes for your investigation.

Assessment of risk

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

SkillBuilder

Measuring your pulse

Taking the radial pulse

1. Place your index and middle fingers on your wrist as shown.
2. Find the area between the tendons of the wrist and the outside bone. You should now be able to feel your pulse.
3. Count the number of beats for 15 seconds. Calculate the heart beats per minute by multiplying this number by 4.



Taking the carotid pulse

1. Place the tips of your index and middle fingers on one side of your neck.
2. Find the area between the muscle and your windpipe as shown and press gently. You should now be able to feel your pulse.
3. Count the number of beats for 15 seconds. Calculate the heart beats per minute by multiplying this number by 4.



Example

Amy counted 17 pulses in her carotid artery in 15 seconds. Therefore, her heart rate is 17 multiplied by 4 which equals 68 beats per minute.

Results

Construct a table to record the results of your experiment.

Conclusion

Explain how well your results support your hypothesis.

Evaluation

Evaluate the validity of your experiment, including suggesting any improvements that could be made to improve the validity.

GO TO
Toolkit section 4.2, Evaluating validity

2.6 Organ dysfunction

Learning intention

To understand how a cell or tissue disorder causes organ dysfunction

Success criteria

SC 1: I can name a disease that is caused by the dysfunction of an organ system.

SC 2: I can explain how a disorder in a cell or tissue can cause an organ to dysfunction.

SC 3: I can describe medical interventions that can resolve or reduce the effects of an organ dysfunction.

KEY TERMS

dysfunction the impaired or abnormal functioning of a tissue, an organ or a system within the body

disease an illness or a sickness that can be characterised by specific signs or symptoms

Lesson overview

The body is complex. It is made up of many different specialised cells, tissues, organs and systems that all need to coordinate to maintain function. When parts of the body are not able to function correctly, this can lead to dysfunctions in those parts of the body as well as other body systems. Dysfunctions of the body are common causes of diseases that may require medical treatment. For example, asthma is a common disease that requires medical treatment to help the lungs function.

In this lesson, you will learn about common disorders that can lead to organ dysfunction and how medical professionals are able to assist people in treating conditions.

SC 1 I can name a disease that is caused by the dysfunction of an organ system

The respiratory system and circulatory system are vital in supplying gases and nutrients to all areas of the human body. These systems are made up of many different organs, tissues and specialised cells that interact with each other. When there is a **dysfunction** in one of these systems, another system is often affected. For example, if the respiratory system were unable to take in enough oxygen, then the heart would not have enough oxygen to pump blood. The heart would not be able to supply the body with oxygenated blood that is necessary for the function of other muscles and organs.

Dysfunctions in the respiratory system

The lungs are important in the uptake and supply of oxygen to cells within the body. If cells cannot be oxygenated, then they are unable to carry out cell functions such as cellular respiration, which is important for survival. Some **diseases** caused by dysfunctions of organs within the respiratory system are:

- asthma (Figure 2.6.1)
- chronic obstructive pulmonary disease (Figure 2.6.2)
- cystic fibrosis
- lung cancers.



FIGURE 2.6.1 Asthma is a common disease that can cause a disorder in the function of the lungs.

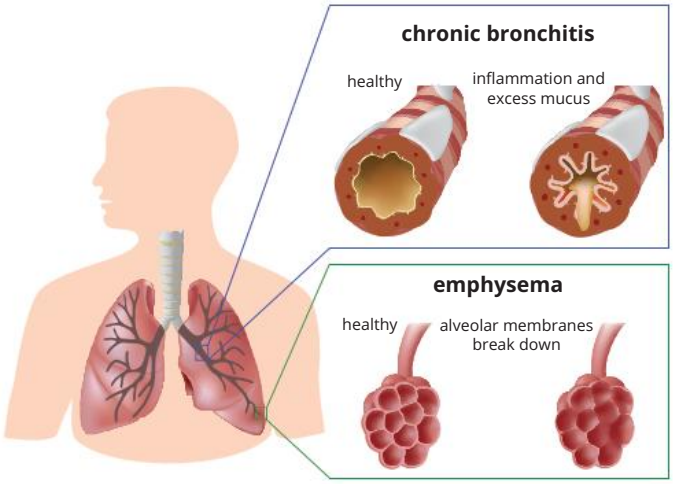


FIGURE 2.6.2 Chronic obstructive pulmonary disease (COPD) occurs when chronic bronchitis or emphysema inflames or damages the lungs, reducing airflow and preventing adequate oxygen from reaching the bloodstream.

Dysfunctions in the circulatory system

The circulatory system is the transport system that supplies blood to all areas of the body, with a large amount going to organs and muscles. Blood is responsible for the transport of oxygen and nutrients and the removal of carbon dioxide and waste products. If the heart is unable to pump the blood well enough, then cells may not receive important nutrients for chemical reactions or be able to remove wastes. Some diseases that are caused by dysfunctions of organs within the circulatory system include:

- aortic disease (Figure 2.6.3)
- peripheral arterial disease (Figure 2.6.4).

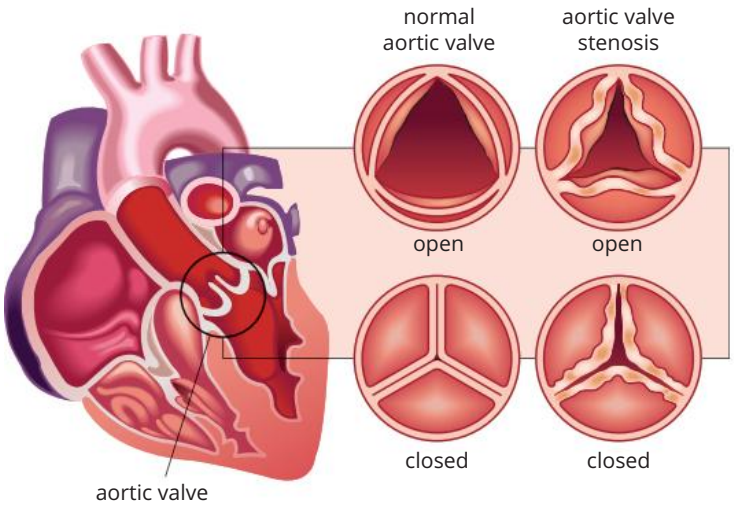


FIGURE 2.6.3 Aortic disease occurs when the valve between the left ventricle and aorta does not open or close correctly; this change in valve function means blood is not pushed forcefully into the aorta; this can increase the chance of other dysfunctions such as changes to heart rhythm, stroke or even heart attack.

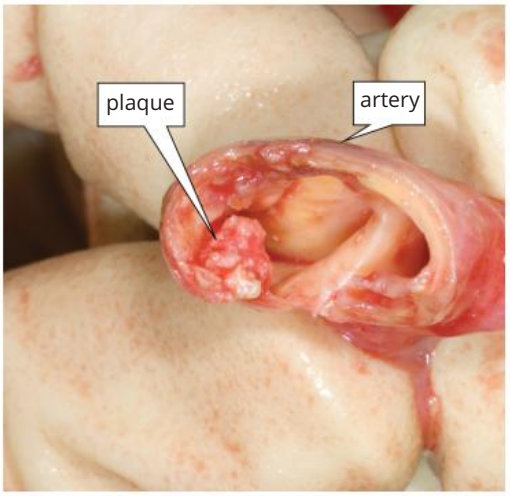


FIGURE 2.6.4 The blockage of arteries by plaque is a type of peripheral arterial disease; narrowing affects the ability of blood to be effectively transported to and from the heart.



FIGURE 2.6.5 A healthy lifestyle may lower the risk of developing certain diseases.

There are many factors that contribute to the dysfunction of cells and tissue that can lead to diseases in organs.

These diseases can be:

- genetic and passed on from parents to children
- from an infection or disease within the body
- from lifestyle choices such as smoking, poor diet and not enough exercise
- from the result of the environment.

Sometimes the cause of a disease is unknown. Different diseases affect the body in different ways, so medical professionals and scientists are always searching for ways to reduce the impact of disease.

A healthy lifestyle may reduce the chance of some diseases occurring in the body.

SC 1 CHECK YOUR UNDERSTANDING

Identify a disease that can cause dysfunction in the respiratory system.

SC 2 I can explain how a disorder in a cell or tissue can cause an organ to dysfunction

KEY TERM

disorder an illness that disrupts normal physical or mental functions of an organism

Many diseases and **disorders** that cause an organ to dysfunction start at the lowest level of organisation: within the cells and tissues that they are made of. Damage and dysfunction of cells and tissues can occur for a variety of reasons and sometimes it is unknown why a particular dysfunction has arisen.

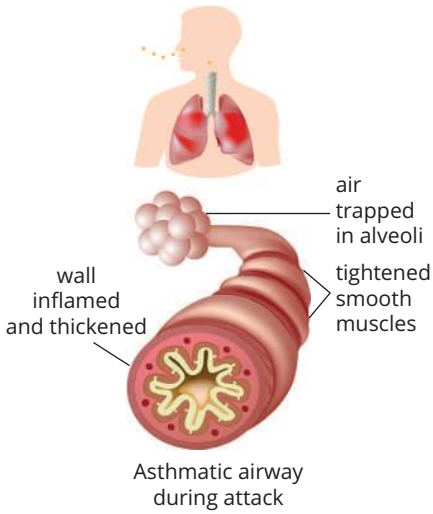


FIGURE 2.6.6 An asthmatic bronchial tube during an asthma attack

The respiratory system

In order for the lungs to function effectively, the bronchioles contain specialised cells known as epithelial cells that have cilia (very fine hair-like structures) that sweep away any dust and debris. The lungs also have a very thin layer of muscle tissue to keep the bronchioles open, which are only a few millimetres wide. When a person is asthmatic, the bronchioles become inflamed (tissues become swollen and red), and this reduces the diameter of the tube (Figure 2.6.6). This makes it difficult for air reaching the alveoli.

The circulatory system

The heart is the key organ in the circulatory system. Without it, the blood couldn't be pumped throughout the body. The heart has four chambers. The chambers on the left side pump oxygenated blood through the aorta to the muscles and organs. The chambers on the right side receive deoxygenated blood and transport it to the lungs to be oxygenated.

Coronary arteries supply the muscle tissues of the heart with oxygenated blood. This allows the mitochondria within the heart's cells to create energy and the heart is able to pump.

What happens when supply is blocked?

When plaque, a substance made up of fatty deposits, builds up inside the coronary arteries it reduces the width of the blood vessels. This can reduce the supply of blood to the heart muscles. This stops the mitochondria within the cells of the heart producing energy and the heart muscle tissue cannot pump blood, leading to a heart attack (Figure 2.6.7).

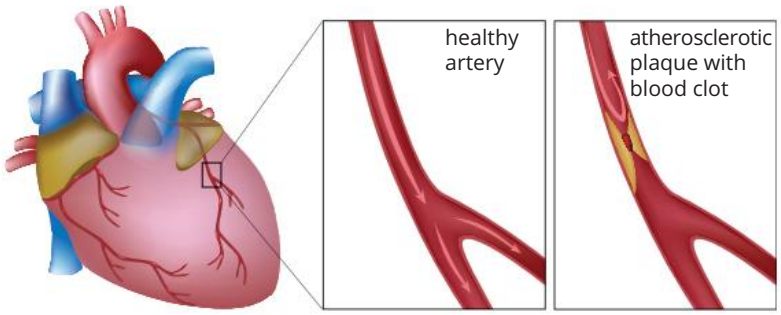


FIGURE 2.6.7 Anatomy of a heart attack

SC 2 CHECK YOUR UNDERSTANDING

Explain how reducing the width of blood vessels can affect the cardiovascular system.

SC 3 I can describe medical interventions that can resolve or reduce the effects of an organ dysfunction

Scientists and medical professionals are always researching ways to manage and treat dysfunctions in the human body.

Treating plaque build-up in the heart

A **stent**, an artificial tube (stent angioplasty), can be used to open up the arteries where there is plaque build-up (Figure 2.6.8). Stents can either reduce the chance of a heart attack occurring as they widen the artery or be used following a heart attack, to keep the artery open to prevent further damage.

KEY TERM

stent a small mesh tube that holds passages open in the body

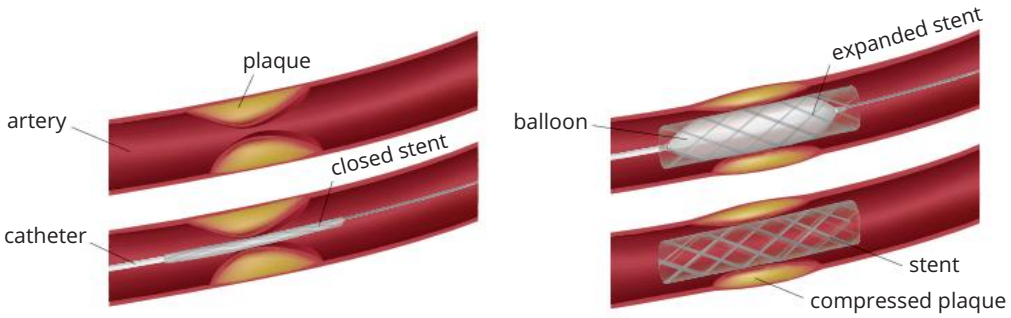


FIGURE 2.6.8 Stent angioplasty

Artificial and biological tissue valves

Some people with aortic valve dysfunction have their valves replaced with artificial or biological valves (Figure 2.6.9). These biological valves are made of animal or human tissues. Use of these valves increases the oxygenated blood supply to the body by repairing this moving tissue.

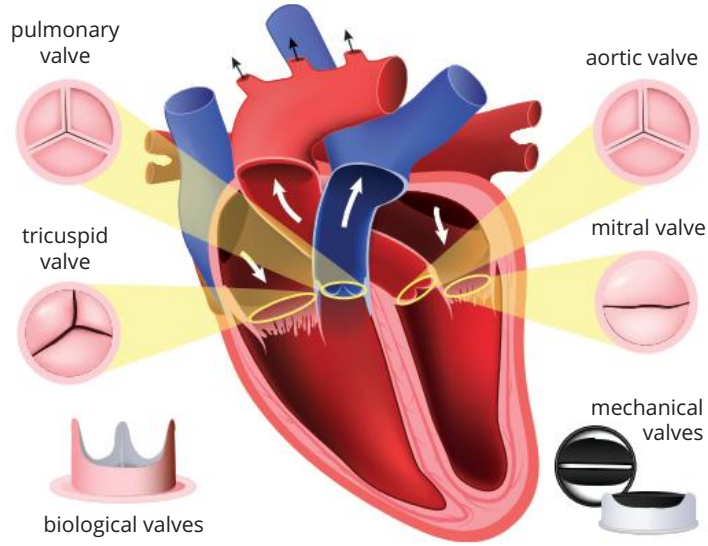


FIGURE 2.6.9 Heart valves

SC 3 CHECK YOUR UNDERSTANDING

Describe how a stent is used as a medical intervention for organ dysfunction.

Lesson review

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

1. Identify one disease caused by the dysfunction of an organ system.
2. Identify two causes of disease in organs.
3. Describe how the dysfunction of lung tissue can lead to respiratory diseases such as asthma.
4. Describe the impact on the body if cells cannot be oxygenated.

2.7 Medical imaging

Introduction

Over time, microscopes and medical imaging have led to an improved understanding of cells and organs.

Before the invention of microscopes, scientists did not have a clear understanding of cells or how they function. Now, with the help of microscopes, it is possible to see cells in much greater detail and understand their structures and functions.

Medical imaging techniques such as **X-rays** and **magnetic resonance imaging** (MRI) allow scientists and doctors to see inside the body and study organs in detail without invasive surgery. This has revolutionised the way illnesses are diagnosed and treated. Diseases can now be detected at earlier stages and with more effective treatments. Images of the inside of the brain are also possible with medical imaging, which has led to a greater understanding of its mechanisms and the development of treatments for brain disorders.

In this inquiry activity, you will examine how microscopes and medical imaging have led to improved understanding of cells and organs.

Background

Microscopes have been essential tools for scientists studying cells and organisms. With high-powered microscopes, scientists can see structures within cells that were previously impossible to observe (Figure 2.7.1). Microscopes can be used to perform biopsies of tissues and organs, allowing scientists and doctors to magnify the samples and observe cell structures in detail.

This has led to ground-breaking discoveries in the field of biology, such as understanding how bacteria cause disease. Similarly, **medical imaging** has been vital in advancing understanding of disease processes.

For example, medical imaging has allowed researchers to observe the progression of cancer and other diseases in real time, enabling them to develop better treatment options. Medical imaging has also helped scientists identify new disease markers and biomarkers, which are important tools for diagnosing and monitoring diseases.

Aim

To examine how microscopes and medical imaging have led to improved understanding of cells and organs

Plan

1 Describe how microscopes are used to explore cells and organs. You can use your own knowledge from previous topics and conduct research into the current use of microscopes.

Learning intention

To be able to examine how microscopes and medical imaging have led to improved understanding of cells and organs

Success criteria

SC 1: I can explain how microscopes are used to explore cells and organs.

SC 2: I can describe how medical imaging has evolved over time.

SC 3: I can evaluate how medical imaging supports the identification and treatment of diseases.

KEY TERMS

X-ray high-frequency electromagnetic radiation that can penetrate materials

magnetic resonance imaging a medical imagining technique that uses a magnetic field and radio waves to create three-dimensional images

medical imaging techniques to create two- and three-dimensional images of parts of the body, normally used to identify medical problems



FIGURE 2.7.1 Microscopes and medical imaging have led to an improved understanding of cells and organs.

GO TO
Toolkit section 5.3, Using artificial intelligence (AI) in science writing

2 Research different types of medical imaging techniques to complete a summary table in your workbook, like the one shown below. An example of ultrasound has been completed for you.

Imaging technique	What can be detected by the imaging process
Ultrasound	soft tissues that are close to the skin such as blood vessels
X-ray	
CT scanning	
MRI	
MRI contrast	
PET scanning	

3 Chose two techniques to research further and explain how the techniques are used to identify and treat diseases.

Design

1 Research how medical imaging has evolved over time and make summary notes.

2 Provide an example of how modern imaging technology provided a breakthrough in the identification and treatment of a type of disease.

GO TO
Toolkit sections 5.1, Methods for presenting scientific ideas and 5.2, Using scientific language

Create

Create a presentation outlining how microscopes and medical imaging have led to improved understanding of cells and organs. Your teacher will give you guidance as to the format for your presentation. You can use any of the information that you have discovered in the planning and design phase of the activity.

Improve

Explain how you could improve your research and presentation of the information about microscopes and medical imaging.

Evaluate

Evaluate the ideas presented and the skills you learnt in your investigation.

2.8 Artificial organs

Introduction

Is it possible that a worn-out body part could simply be replaced with a new one?

Artificial organs have been able to assist people overcome the burden of disease for hundreds of years. Technological advancements increase the number of diseases that can be treated using artificial and donated organs. This is a developing field in which scientists can use cutting-edge technology to change the way people are medically treated. New technology is constantly being developed to improve medical treatments (Figure 2.8.1).

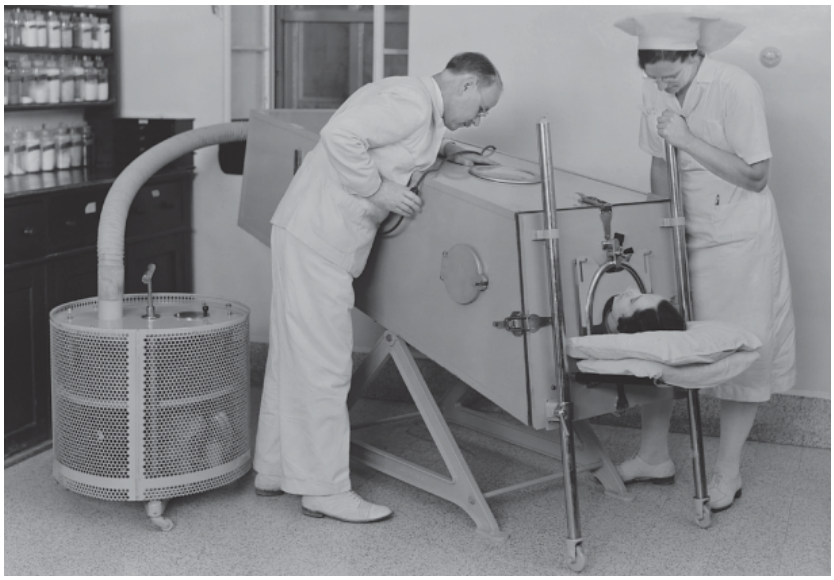


FIGURE 2.8.1 The science of artificial organs has progressed significantly since the 'iron lung' used to assist the breathing of this polio patient in the 1940s.

In this inquiry activity, you will research and investigate how artificial organs have been developed to treat disease, as well as the ethical implications of artificial organ use.

Learning intention

To be able to explain how an artificial organ supports the function of a living system

Success criteria

SC 1: I can describe examples of artificial organs that have been used in the human body.

SC 2: I can describe an example of how improvements in technology have resulted in improvements to artificial organs.

SC 3: I can analyse ethical issues that may arise from artificial or donated organs.

Background

Artificial organs and organ transplants have been employed for hundreds of years to treat a range of diseases and disorders. The first known artificial body parts were prosthetic limbs, developed by ancient Egyptians to treat damaged arms, legs, fingers and toes. These are not organs, but, over time, artificial organs themselves were developed. The use of these artificial and transplanted organs has changed rapidly with technological advancements.

People are now able to access a range of life-saving devices that allow the treatment of diseases and other medical conditions.

The ethics of artificial and transplanted organs in society is taken into careful consideration by scientists when developing new advancements, and most new advancements must pass specific ethical guidelines before their development.

Aim

To investigate how improvements in technology and changes to ethical perspectives have assisted in the development of artificial organs to treat medical conditions

Plan

Plan how you will carry out your research.

GO TO
Toolkit section 5.3, Using artificial intelligence (AI) in science writing

1. Research the first artificial organs used to treat disease.
2. Construct a timeline to show the development of different artificial organs throughout history.

Design

1. Describe what you notice about the changes in the use of artificial organs over time.
2. Describe some ethical considerations of artificial or transplant organ use.
3. Consider how you might present a specific artificial organ to the class, including its history, diseases treated, technological advancements and ethical considerations. What platform would you use for this communication? What key headings and criteria would you need? If you are working in a group, how could you work as a team to research different aspects?

Conduct

GO TO
Toolkit sections 5.1, Methods for presenting scientific ideas and 5.2, Using scientific language

In your team or group, use your combined research from your planning and designing to create a presentation that describes the history, use of and technological advancement in artificial organs or a specific artificial organ. Also explain the ethical implications of artificial organ use to treat disease.

Improve

1. How could you improve your presentation or how you obtained your information?
2. Explain whether you would you change any key headings or the platform you used to present this information.
3. Comment on whether you felt you shared your topic about artificial organ use effectively.

Evaluate

In this activity, you planned and conducted an inquiry into the way artificial organs have been and are still used today, as well as the technological changes and the ethical considerations in their use. What skills did you use during this activity?

2.9 Ethical impacts of organoids

Lesson overview

Organoids are tiny, simplified organs that are grown from a few stem cells (Figure 2.9.1). They mimic the structure and functions of human organs and have become a hot topic of research in the medical field due to their potential to provide insights into human diseases and drug testing. However, as with any new technology, the development of organoids raises ethical concerns that must be considered.

Organoids can be used for a variety of purposes, including research, transplantation and testing, which raises questions about ownership, consent and the value of human life.

In this lesson, you will learn about the ethical implications of the development of organoids and their impact on society.

Learning intention

To understand the ethical impacts of the development of organoids

Success criteria

SC 1: I can describe an organoid.

SC 2: I can explain potential impacts of the use of organoids in medical research and treatments.

SC 1 I can describe an organoid

An **organoid** is a small, 3D structure made up of cells that are grown in a laboratory. Organoids are designed to look and function like a specific organ in the body, such as the brain, liver or intestine (Figure 2.9.2). The process of creating an organoid involves using stem cells from the human body. **Stem cells** are special cells that can develop into many different types of cells. Scientists can encourage these cells to grow in a certain way by changing the environment they grow in.

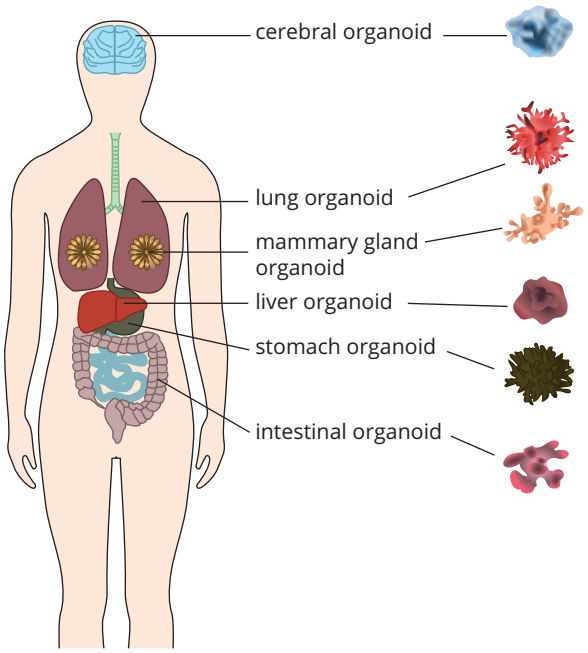


FIGURE 2.9.2 A range of human tissues and organs can be 'recreated' using organoids.

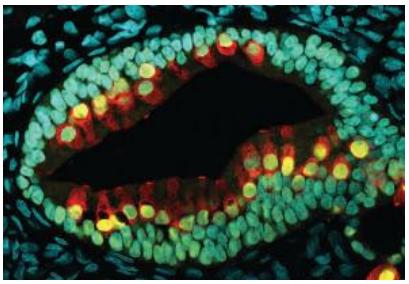


FIGURE 2.9.1 An electron microscope image of a 'mini inner ear', or an organoid created from human stem cells

KEY TERMS

organoid artificially grown cells that resemble an organ
stem cell a cell that can develop into different types of cells under specific conditions

The use of organoids

Organoids serve as valuable tools for studying diseases and developing new treatments. For instance, to investigate how a particular disease affects the liver, scientists can create an organoid that mimics the liver's structure and function. By observing how the disease interacts with the organoid, researchers can gain deeper insights into its effects and contribute to the development of more effective treatments.

Another key application of organoids is drug testing. Growing organoids in a lab improves the ethics of drug development by reducing reliance on human and animal testing. Testing new drugs on organoids can accelerate the process while addressing ethical concerns in medical research.

Organoids as a new technology

The development and use of organoids is a relatively new field of science. The first successful brain organoid was created in 2012. Scientists are still exploring their potential uses and many more uses might emerge in the next few years as the technology around organoids improves. Organoids hold a lot of promise for advancing our understanding of the human body and developing new treatments for a wide range of diseases.

SC 1 CHECK YOUR UNDERSTANDING

Describe what an organoid is.

SC 2 I can explain potential impacts of the use of organoids in medical research and treatments

The development of organoids offers new opportunities to study diseases and develop new treatments (Table 2.9.1). Organoids have the potential to speed up the development of new drugs by testing them in a Petri dish rather than going through the long process of testing on animals or human subjects. This also reduces the number of animals used in research—an ethical win for some. Additionally, organoids can be used to study diseases that were previously difficult to model, such as neurological disorders that affect the brain and/or the central nervous system. This can lead to new treatments and cures.



FIGURE 2.9.3 Scientists working with live animals must follow guidelines to minimise harm to the animal when possible.

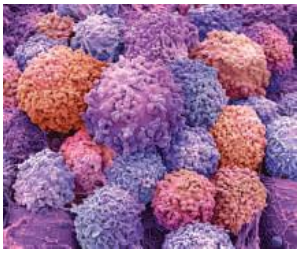
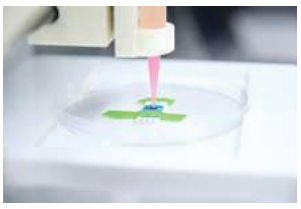
Organoids and live testing of animals

The use of animals in research has led to many important discoveries and advancements in medical treatments, which have saved the lives of millions of humans. However, there are several ethical issues to consider: Is it right to use animals for the benefit of humans? Do the animals experience any unnecessary pain or suffering during the research process?

Scientists must ensure that the animals are treated humanely and that their suffering is minimised as much as possible (Figure 2.9.3). This includes providing them with adequate food, water and shelter, as well as ensuring that they receive proper veterinary care when needed.

Using organoids can reduce the need for some animal testing.

TABLE 2.9.1 Examples of organoid use in medicine

Disease modelling	
Organoids can be used to model various diseases, such as cancer, cystic fibrosis and Alzheimer's disease. Studying the effect of pathogens (organisms that cause disease) or other disorders on cells in these organoids allows scientists to gain a better understanding of how the diseases develop and how they can be treated.	 This is a coloured scanning electron micrograph (SEM) of a neural cell in an organoid. The effect of pathogens on these cells can be analysed to investigate the development of diseases.
Drug testing	
Organoids can be used to test the safety and efficacy of new drugs. By testing drugs on organoids, scientists can determine whether they are likely to be effective in humans before moving on to more expensive and time-consuming clinical trials. This would reduce the reliance on animal testing for drugs.	 This experiment is testing the effect of an antibiotic in the laboratory.
Personalised medicine	
Organoids can be created using a patient's own cells, which allows for highly specific, personalised medical intervention. For example, if a patient has a form of cancer, an organoid can be created using cells from their tumour and various drugs can be tested on the organoid tumour to determine which drugs are most effective at reducing the cancer in their body.	 Cells from a tumour, such as the pictured skin cancer, can be used to grow organoids used for testing treatments on the cells outside of the body.
Tissue engineering	
Organoids can be used in tissue engineering, the process of creating new tissues and organs for transplantation. Scientists can learn how to grow tissues and organs for transplants in humans by using cells created by organoids in a lab.	 3D bioprinting can be used to create structures from living cells.

SC 2 CHECK YOUR UNDERSTANDING

Identify one use of organoids in medical research.

Lesson review

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

1. Describe how the use of organoids can make drug testing more ethical.
2. Identify two ethical considerations when using animals for live testing
3. Explain how organoids are created in the laboratory.
4. Describe how the use of organoids can reduce the need for animal testing.

2.10 Transportation of water in plants

Learning intention

To understand how and why water is transported in a plant

Success criteria

SC 1: I can describe the purpose of water transport in plants.

SC 2: I can explain the role of cells and tissues in the transport of water in plants.

SC 3: I can predict the effects of damage to plant roots or stems in relation to the transport of water.

KEY TERMS

vascular system a system of hollow tubes or vessels that transports water and nutrients around an organism

photosynthesis the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from sunlight

Lesson overview

Plants are complex multicellular organisms that have a range of specialised cells, tissues and organs that allow them to function.

In this lesson, you will learn about the types of specialised cells and tissues that allow the movement of water within the plant and enable photosynthesis to occur.

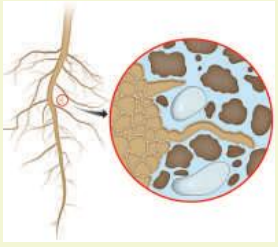
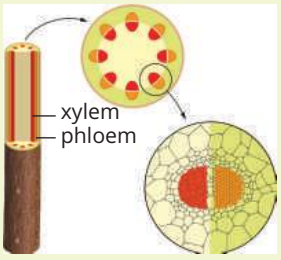
SC 1 I can describe the purpose of water transport in plants

Like animals, plants are multicellular organisms that have specific requirements to grow and survive. Although plants are not as complex as animals, they are also composed of cells, tissues, organs and systems. Plant organs include roots, stems and leaves. Both plants and animals have a highly specialised **vascular system** that is capable of transporting water, gases and nutrients to different organs.

Parts of a plant

The uptake of water is vital for the overall function of a plant as it needs to transport water to the leaves for **photosynthesis** to occur (Table 2.10.1). Water also assists in many other cellular functions and helps maintain the rigidity of the plant to keep it upright. Without water, plants may wilt and die.

TABLE 2.10.1 Plant structures that assist in the uptake and movement of water

Roots	Xylem	Leaves
Have specialised root hairs able to take in more water from the soil and create air pockets to keep the roots healthy	A long narrow cylindrical structure contained in the stems that allows water to be transported up the plant from the roots	Have a detailed network of veins that contain xylem tissue that allows the water to transport from the stem to the photosynthetic cells in the leaf
		

SCIENCE IN SOCIETY

Water transport in plants

In Australia, understanding water transport in plants is crucial for agriculture. Farmers need to ensure that crops receive enough water to grow. Research into water transport helps improve irrigation techniques and crop yields.
For example, drip irrigation (Figure 2.10.1) is a more effective method of watering plants than sprinkler or surface irrigation as it delivers water directly to a plant's roots, reducing the evaporation that happens with other watering methods.



FIGURE 2.10.1 Drip irrigation is an efficient watering method because it delivers water directly to the roots of the plant.

Water and photosynthesis

Water travels through the plant from the roots to the leaves where it is used in photosynthesis (Figure 2.10.2). Photosynthesis is a complex process in which chlorophyll, the green pigment in **chloroplasts**, captures sunlight energy. This energy is used to split water molecules and produce glucose (a type of sugar) for the plant. The process also creates oxygen as a by-product. That oxygen is released into the atmosphere and breathed in by humans. Sugars are transported in the **phloem** of the plant, which is a long tube near the **xylem**.

KEY TERMS

chloroplast an organelle within a plant cell where photosynthesis takes place
phloem a plant tissue that carries glucose from the leaves to all other parts of the plant
xylem a plant tissue that carries water from the roots to the rest of the plant

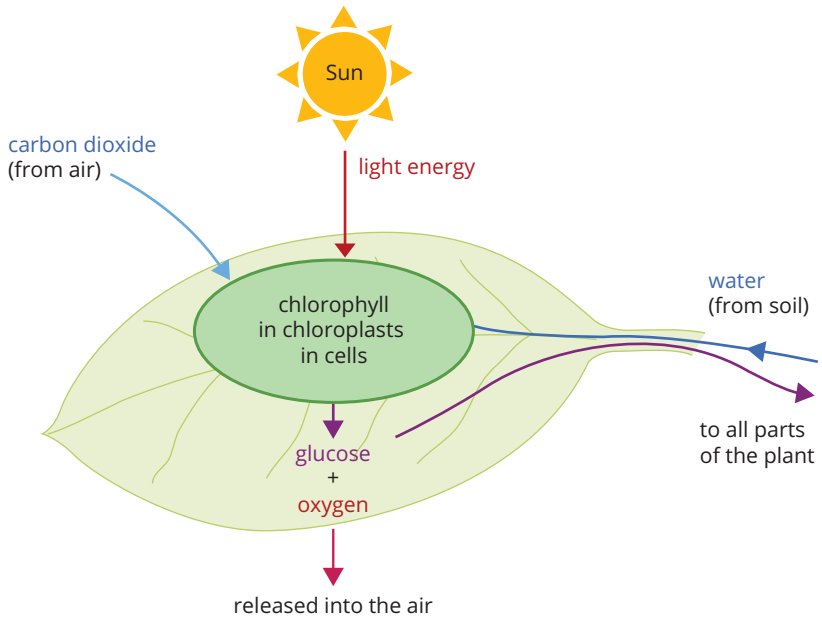


FIGURE 2.10.2 The process of photosynthesis requires water from the soil. Photosynthesis takes place in the chloroplasts of leaf cells. Chloroplasts contain the green chemical chlorophyll.

SC 1 CHECK YOUR UNDERSTANDING

What is the main purpose of water transport structures in plants?

SC 2 I can explain the role of cells and tissues in the transport of water in plants

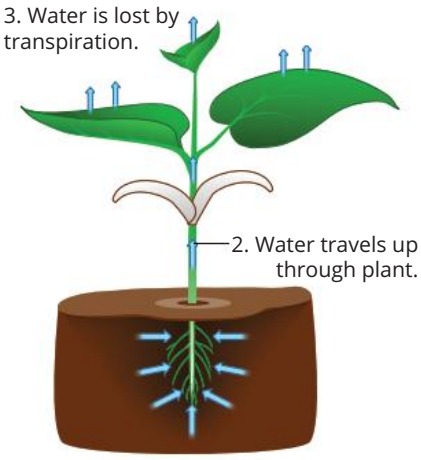


FIGURE 2.10.3 Water movement through a plant

KEY TERMS

transpiration the passive movement of water through a plant and its evaporation from the leaves

root the underground part of a plant that absorbs water and nutrients from the soil

root hair an extension on the outer surface of some root cells that increases the surface area for water absorption

tracheid a narrow tube-like cell in xylem tissue

Plant cells

Plants have highly specialised cells that are capable of different functions. Plant cells have cell walls, chloroplasts and large contractile vacuoles.

Although most plant cells have a similar basic structure, different cells in a plant can have specialised functions. This creates tissues and organs that are able to perform a range of functions within the plant.

Maintaining water balance is a function that is vital to a plant's survival. The plant's vascular system transports water from the roots to the leaves. Water is either used by the plant or lost through the leaves via evaporation. The process of water moving through the plant and the evaporation of water from the leaves is called **transpiration** (Figure 2.10.3).

Root cells

Roots play a crucial role in the absorption of water from the soil. **Root hairs** on the outer layer increase the surface area for water uptake (Figure 2.10.4).

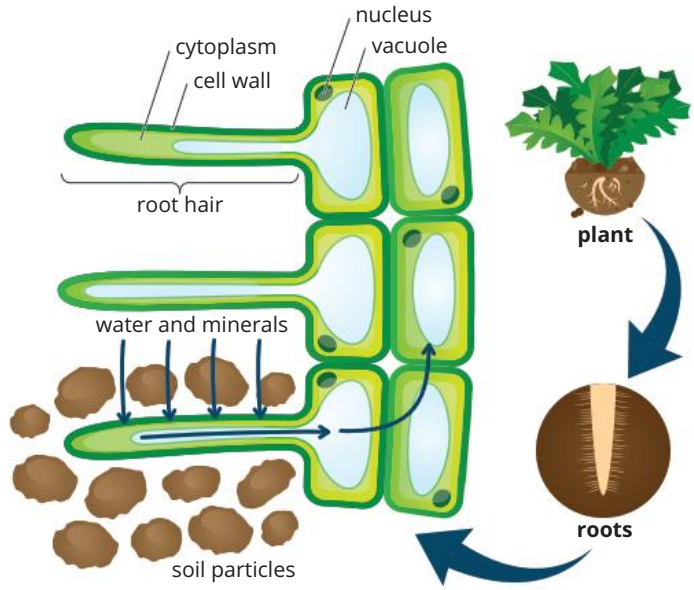


FIGURE 2.10.4 The movement of water through root hair cells

Xylem cells

Xylem is present in plant stems. This specialised tissue forms a cylinder, which assists with the movement of water from roots to stems. Xylem tissue has specialised cells called xylem vessels and **tracheids**—long cylinder-shaped cells. When arranged as a tissue, these cells form a continuous tube with small holes, known as pits, for water passage between xylem vessels (Figure 2.10.5).

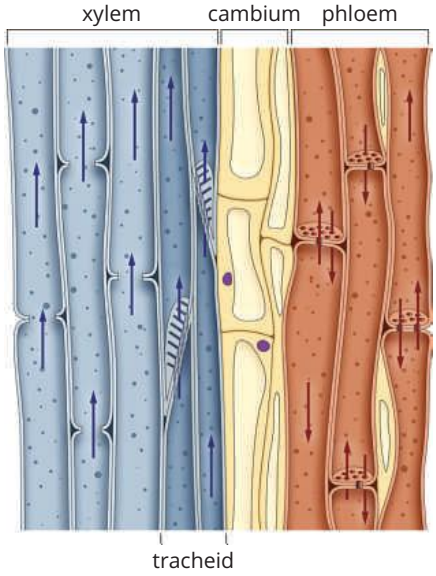


FIGURE 2.10.5 Cylinder-shaped xylem vessels are bunched together with cambium (another tissue type) and phloem to form the vascular bundle.

Scifile

Capillary action

Capillary action is the process that allows water to move up narrow tubes against gravity. This phenomenon helps water travel through the xylem tubes in plants, ensuring that all parts of the plant receive the necessary hydration.

Leaf cells

Leaves consist of various cell layers (Figure 2.10.6). The palisade cells in the image are the main cells for photosynthesis that need water from the plant.

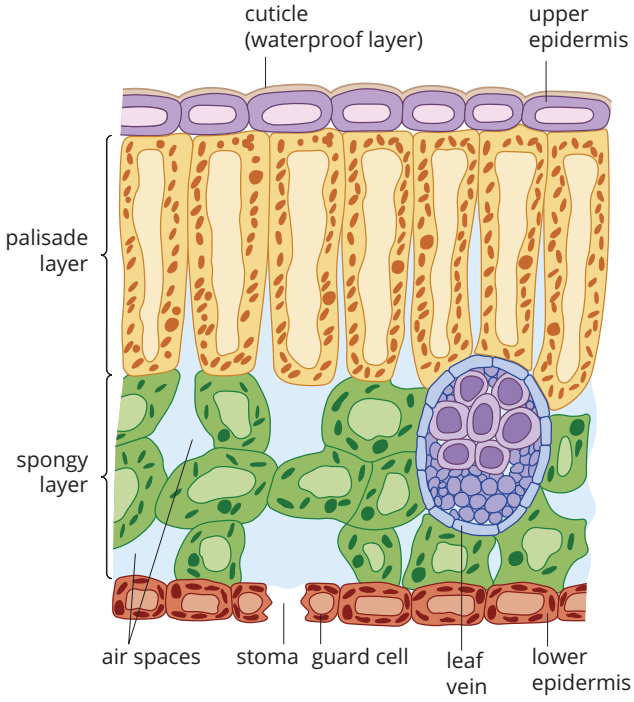


FIGURE 2.10.6 A diagram of specialised leaf cells

SC 2 CHECK YOUR UNDERSTANDING

Explain how xylem cells allow the transport of water through the plant.

SC 3 I can predict the effects of damage to plant roots or stems in relation to the transport of water

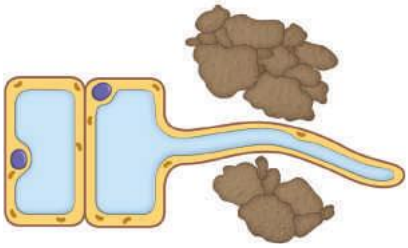


FIGURE 2.10.7 Root cells need space between the soil crumbs to take up water.

Root hair damage

Root hairs are useful if there is space between the soil crumbs that surround them (Figure 2.10.7). The space provides oxygen for cellular respiration to make energy for the cell. If the spaces are removed, then the root cells cannot get enough oxygen and the root cells will die. This will then stop the plant from taking up water, which causes cells that require water higher up in the plant to stop functioning, potentially resulting in the death of the plant.

Whole root damage

If enough roots are still intact when moving a plant, then the plant may be able to grow new roots. However, if too many root cells have been removed, then the plant will not be able to take water into its xylem tissue. This would reduce the amount of water that reaches the leaves where it is required for photosynthesis.



FIGURE 2.10.8 The flow of water to the leaves is reduced if the stem is damaged.

Squashed stems

If the stem of a plant is squashed or damaged by animals or wind, then the xylem may be damaged and the flow of water to the leaves could be reduced, and this affects the amount of photosynthesis that can occur (Figure 2.10.8).

SC 3 CHECK YOUR UNDERSTANDING

What happens to a plant if its roots are damaged?

Lesson review

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

1. State the name of the process that moves water from a plant's roots to its leaves.
2. Identify the main tissue responsible for water transport in plants.
3. Explain why water transport is essential for plant survival.
4. Explain how xylem cells are specialised for water transport.
5. Describe how a plant might respond to damage in its root system.

2.11 Investigating transport in plants

Introduction

Plants take in water and nutrients though their roots and carry out photosynthesis in the leaves to make glucose. These vital substances support growth, repair and other functions in the plant. Specialised tissues in the roots, stems and leaves form the plant's vascular system, which is responsible for transporting these vital substances. Environmental factors can influence the rate of water transport in plants.

In this practical investigation, you will explore water intake through vascular tissues in various environments.

Learning intention

To be able to conduct an investigation to observe the transport of water in a plant

Success criteria

SC 1: I can draw a scientific diagram to communicate findings from an investigation.

SC 2: I can link observations with knowledge of transport through plant systems.

SC 3: I can evaluate the method of an investigation and suggest improvements.

Background

Plants can transport water from their root systems to their leaves through specialised cells and vascular tissue known as xylem. This transport system maximises the amount of water to reach the leaf tissue so that photosynthesis can occur. In different environments, plants use transpiration streaming to transport water at different rates depending on the plant's needs.

Aim

To observe the tissues that transport water in plants placed in different environmental conditions

Hypothesis

If plants are placed in a warmer environment, then the plants will increase their rate of transpiration streaming through the xylem compared to plants at room temperature.

Prediction

Read the method and write a prediction for your investigation.

GO TO
Toolkit section 1.2, Making predictions from observations

Materials

- 2 celery stalks with leaves
- tap water
- blue food dye
- 2 × 250 mL tall beakers
- scalpel blade
- cutting board
- stereo microscope or hand lens
- measuring cylinder
- heated room or small heater

SAFETY NOTE

- Take care when using a scalpel blade not to cut yourself.



FIGURE 2.11.1 Place the celery stalks into the beaker.

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

Prepare the celery

1. Use a scalpel to cut the bottom off two celery stalks.
2. Place 150 mL of water into each beaker.
3. Add five drops of food dye into each beaker.
4. Place one celery stalk into each beaker (Figure 2.11.1).
5. Place one of the beakers with celery in a cool environment (room temperature).
6. Place the second beaker with celery into a warmer environment.
7. Leave both beakers with celery for 2 days.
8. Remove the celery from each beaker.
9. Pour the remaining water from the cool environment into a measuring cylinder and record the amount of water left over.
10. Pour the remaining water from the warm environment into a measuring cylinder and record the amount of water left over.
11. Place the celery on the cutting board and cut a thin 3–5 mm slice from the bottom of the stem, the midway point of the stem and the part of the stem where the leaves attach, as shown in Figures 2.11.2 and 2.11.3.
12. View each slice of celery using a stereo microscope or a hand lens. Lay the slice flat on a white background to view the structure of the vascular tissue.

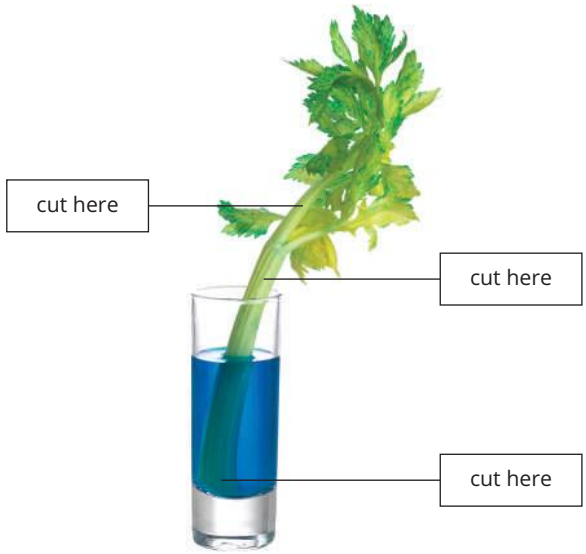


FIGURE 2.11.2 Cut the celery stalks as shown.



FIGURE 2.11.3 The slices at each section of the plant will look like this, but the xylem vessels may show evidence of the food colouring.

Results

1 Draw and label a diagram of each of the three celery slices.

2 Copy the table below into your workbook to record your results.

	Initial volume of water (mL)	Final volume of water (mL)	Difference in volume of water (mL)
Plant in cool environment			
Plant in warm environment			

Conclusion

1 Identify the tissue in the transport system of the celery that the water moved through.

2 Explain how you were able to determine that water moves through the celery plant.

3 Explain the effect of temperature on transpiration streaming in celery plants.

Evaluation

1 List two improvements that could be made to the method of the experiment.

2 Explain how one of the improvements that you listed would make the investigation better.

GO TO
Toolkit section 4.3, Evaluating reliability

2.12 Comparing plant and animal systems

Learning intention

To understand that plant and animal systems can have similar functions

Success criteria

SC 1: I can compare the transport of food in plants and animals.

SC 2: I can compare the transport of water in plants to the transport of blood in animals.

SC 3: I can compare the removal of waste products in plants and animals.

KEY TERMS

autotroph an organism that can make its own energy, usually through photosynthesis

heterotroph an organism that cannot make its own energy and needs to get energy from other sources, mainly by consuming plants and animals

Lesson overview

Plants and animals are complex multicellular organisms that have many different systems to carry out vital functions. Plants have fewer organs and systems than animals, but some of their systems have some similar structures that serve similar functions (Figure 2.12.1).



FIGURE 2.12.1 The body of a butterfly and structure of a dandelion contain organs vital to their survival.

In this lesson, you will bring your knowledge of complex systems to help you learn the differences and similarities in plant and animal systems.

SC 1 I can compare the transport of food in plants and animals

Obtaining energy

Plants and animals need to obtain energy for functions within their cells. Plants are **autotrophs** and can make their own energy by converting sunlight into glucose through photosynthesis. Animals are **heterotrophs** and need to consume their energy from other sources, such as eating and digesting other plants and animals (Figure 2.12.2).

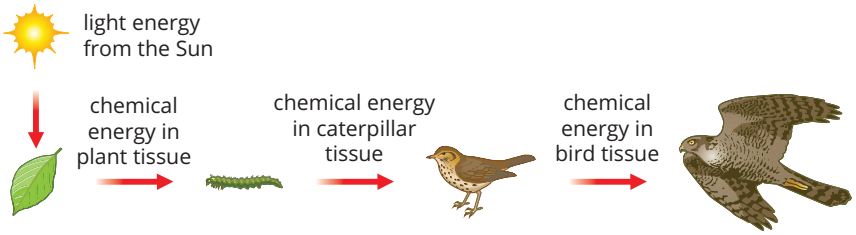


FIGURE 2.12.2 Energy from the Sun is captured by the plant (autotroph) for photosynthesis; animals (heterotroph) obtain energy through consumption.

Transport of food nutrients in animals

In animals, the transport of food nutrients is essential for sustaining life. After digestion, nutrients are absorbed and distributed throughout the body to support various physiological functions.

Sources

Animals must consume their energy to survive. They take in nutrients that are then processed by the body. The digestive system of an animal functions to break down food, both chemically and mechanically so that nutrients can be absorbed into the bloodstream (Figure 2.12.3).

Once food enters the stomach, it is broken down by acids and is churned into smaller pieces to then be digested and absorbed into the bloodstream.

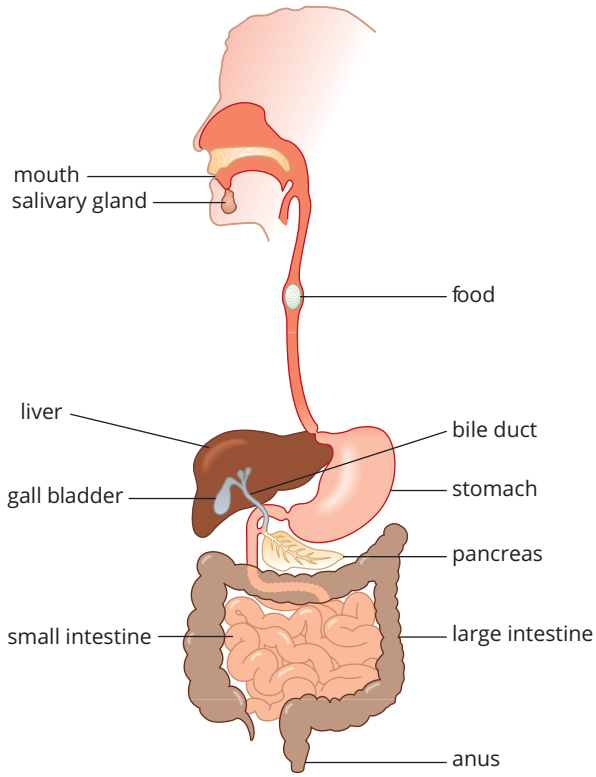


FIGURE 2.12.3 The digestive system of a human

Transport

Once the nutrients enter the bloodstream, they are transported by the cardiovascular system to various body parts. These food-derived nutrients serve a critical role in cellular processes such as cellular respiration, which uses glucose to generate energy.

Storage

Once food has been processed by the body and transported to various sites, it can be either used, stored or excreted as waste.

Transport of nutrients in plants

In plants, the transport of nutrients is crucial for their growth and development. Nutrients produced in the leaves are distributed throughout the plant to different parts that require energy.

Sources

Specialised cells within the leaf create glucose as a product of photosynthesis. The glucose is used by the plant for growth in other areas. The leaf organs are called 'sources' because they are responsible for the production of glucose.

Transport

Glucose is transported through the plant in a tissue called phloem. The phloem is vascular tissue similar to the xylem, but it transports sugars instead of water (Figure 2.12.4).

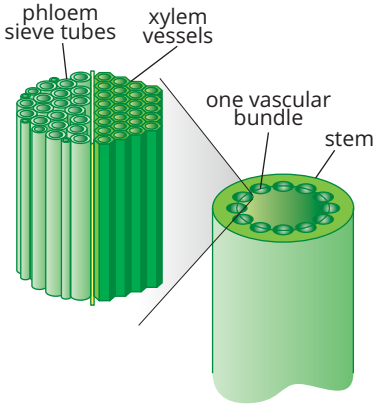


FIGURE 2.12.4 Vascular tissues in plants

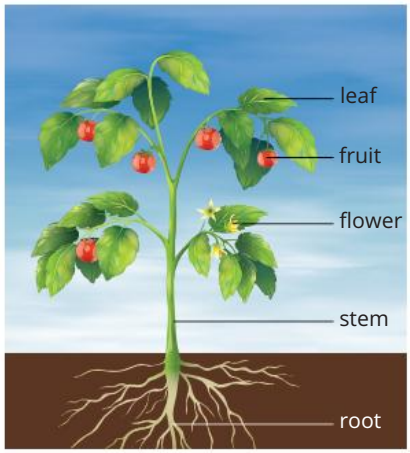


FIGURE 2.12.5 Plant organs

Sinks

Sinks are the areas of the plant that can store and use glucose for active growth. Examples of sinks are flowers, fruits and roots (Figure 2.12.5).

SC 1 CHECK YOUR UNDERSTANDING

Name the tissue in plants that is responsible for transporting sugars.

SC 2 I can compare the transport of water in plants to the transport of blood in animals

Plants and animals have transport systems called vascular tissues. Vascular tissues move substances to areas that need specific nutrients, gases and other molecules.

Scifile

No vascular systems

Most plants have vascular systems that transport essential substances, but some plants, such as mosses, lack vascular systems and are able to absorb water directly into their leaves. These non-vascular plants need to live in moist environments to maintain photosynthesis in their leaves.



Water transport in plants

The xylem and phloem in plants make up the vascular tissue responsible for the movement of substances around the plant. The xylem moves water through its long hollow cells (Figure 2.12.6).

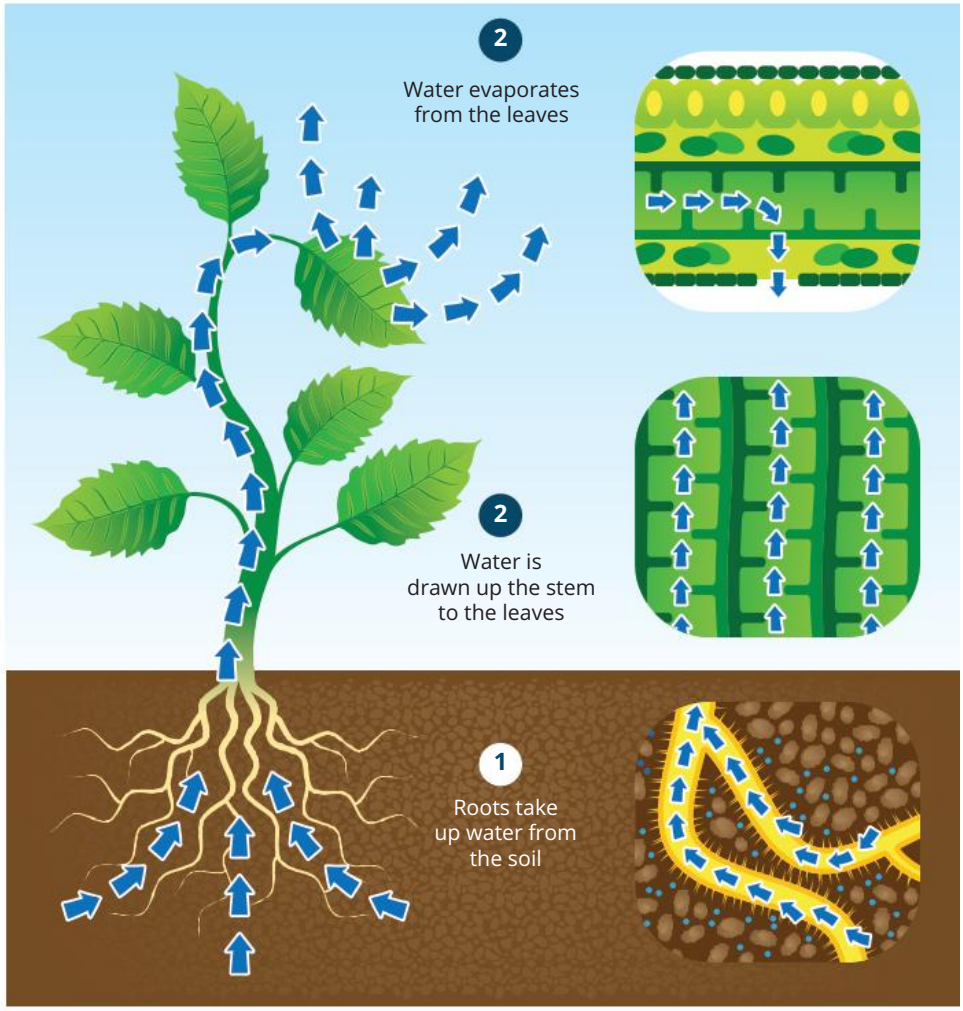


FIGURE 2.12.6 Water travelling through the plant

Vascular tissue in animals

Animal blood moves through the arteries, veins and capillaries in the cardiovascular system (Figure 2.12.7). In this way, oxygen and nutrients are delivered to different parts of the body. This process requires the heart to pump the blood from a central location into the arteries and then return the blood back to the heart through the veins.

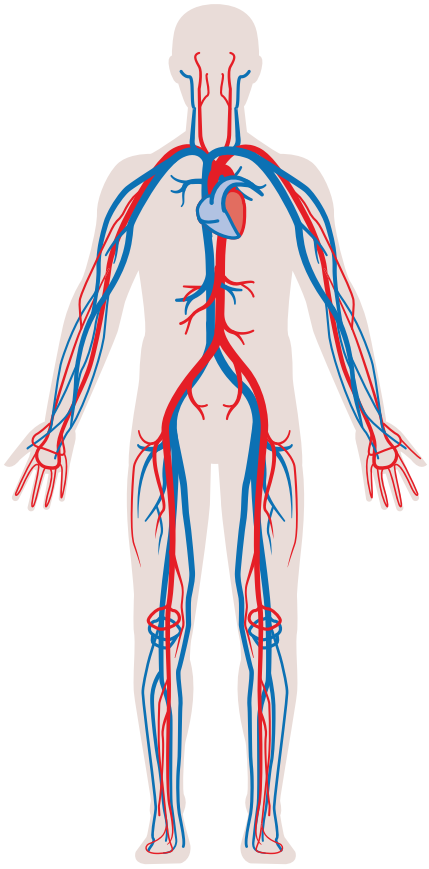


FIGURE 2.12.7 The veins (blue) and arteries (red) of the cardiovascular system

Table 2.12.1 compares the vascular tissue in plants and animals.

TABLE 2.12.1 Comparing vascular tissue in plants and animals

	Plants	Animals
Structure of vascular tissue	Plants have long cylindrical transport systems. Water in plants is transported through xylem.	Animals have long cylindrical transport systems. Blood in animals is transported through veins, arteries and capillaries.
Direction of flow	Xylem in plants transports water in one direction: from the root to other parts of the plant.	Animals' arteries and veins transport blood in one direction, either away (arteries) or towards (veins) the heart. Veins have valves to prevent blood flowing in the other direction.
Movement of substances	Water moves through plants because of mechanical pressure caused by losing water from the leaves, known as transpiration.	The heart's strong muscular contractions pump blood around the bodies of animals. With each heart contraction, a small amount of blood is pushed forcefully into the arteries; this is why many animals have a pulse.

SCIENCE IN SOCIETY

Artificial hearts

Understanding how the circulatory system transports blood helps researchers develop new technologies and treatments. For example, vascular bioengineers are working to create an artificial heart to mimic the complex functions of the human circulatory system (Figure 2.12.8).

These bioengineered organs, like artificial hearts and blood vessels, can potentially reduce waiting times and complications associated with organ transplants, offering patients life-saving medical treatment.



FIGURE 2.12.8 Artificial bio-printed heart valves could help with medical advancements.

DISCOVER MORE

Animal blood contains different components that are used throughout the body. It consists of red blood cells that are capable of carrying oxygen, white blood cells and platelets that are involved in the immune response and body repair, and plasma, which is responsible for the transport of nutrients, hormones, proteins and waste products.

SC 2 CHECK YOUR UNDERSTANDING

Outline one way in which plants and humans transport systems are similar, and one way they differ.

SC 3 I can compare the removal of waste products in plants and animals

When organisms use energy to survive, waste products are created in the process. If these products build up, then the organism's internal environment can become unbalanced, which can endanger the life of the organism. Both plants and animals have waste systems that function to remove these by-products.

Waste products in plants

During photosynthesis, plants use energy from sunlight to convert carbon dioxide and water into glucose and oxygen. Oxygen is a waste product of photosynthesis and is released through tiny openings called stomata on the underside of leaves (Figure 2.12.9).

Some plants that live in highly salty areas such as mangroves can excrete salts from specialised salt glands on the top of their leaves (Figure 2.12.10).

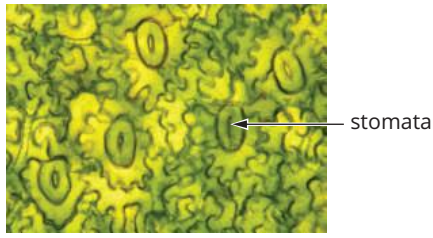


FIGURE 2.12.9 A microscope view of stomata



FIGURE 2.12.10 A leaf of a white mangrove (*Laguncularia racemosa*) with salt deposits from filtration of waste

Waste products in animals

The **excretory system** in animals is a far more complex system than plant waste removal systems. Although animals can remove unwanted carbon dioxide as waste from their lungs, other products also build up within their bodies.

The kidneys play a key role in filtering waste from the bloodstream. Following filtration, blood returns to the circulatory system, and the filtered substances are removed from the body as **urine** (Figure 2.12.11).

KEY TERMS

excretory system the system in the body that processes and removes waste products

urine the liquid waste product of animals that contains a range of substances, including urea, and which is removed from the blood by the kidneys

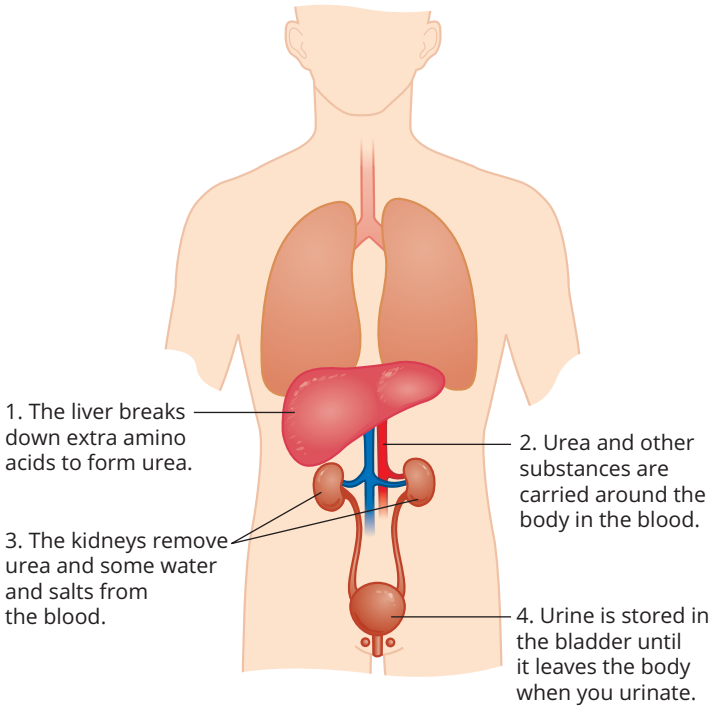


FIGURE 2.12.11 The excretory system in humans filters waste products; urea is the waste product that can build up if the kidneys do not function effectively.

SC 3 CHECK YOUR UNDERSTANDING

Explain how plants remove waste products.

Lesson review

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

1. Identify the tissue responsible for transporting water in plants.
2. Identify one waste product removed by plants.
3. Outline how the phloem transports nutrients in plants.
4. Describe how the circulatory system in animals transports blood.
5. Explain the role of stomata in photosynthesis.
6. Carbon dioxide is a waste product that is produced by animals. Describe how animals remove carbon dioxide.

2 Systems in plants and animals

Topic summary

The key concepts included in this topic are:

- Specialised cells and tissues make up complex systems in both plants and animals.
- Plants and animal systems can have similar functions such as gas exchange and transport.
- Gases are transported in animals through the respiratory system and blood is transported through the circulatory system.
- Water is transported through a plant via roots and xylem.
- Cell or tissue disorders can cause dysfunction in both plants and animals.
- Artificial organs such as stents can support the function of a living system.
- Organoids can have ethical impacts in society.

Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

Remember

1 Name the four main organ systems in the human body.

2 Identify the main structures of the lung involved in gas exchange.

3 Identify the main structures of the heart involved in blood circulation.

4 Identify the names of the left and right chambers of the heart.

Understand

5 Explain why heart rate is likely to increase when a person is exercising.

6 Describe how a microscope can be used to observe plant structures.

7 Describe how improvements in technology have enhanced artificial organs.

Apply

8 Explain how the use of organoids may change the current approaches to drug testing.

9 Explain how the use of an artificial heart would affect a patient's circulatory system.

10 Explain how damage to a plant's roots would affect its water transport system.

Analyse

11 Evaluate the ethical considerations of using organoids in medical research.

12 Compare the structures that transport water in plants to the structures that transport blood in animals.

13 Design an investigation to model water transport in plants.

Extension: Research task

14 Research and describe a recent medical advancement in treating organ dysfunction; for example, the use of stents in cardiovascular disease treatment or gene therapy in cystic fibrosis treatment.

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

alveoli tiny air sacs in the lungs where oxygen from the inhaled air enters the bloodstream and where carbon dioxide from the bloodstream is released into the exhaled air

aorta the largest artery in the body, carrying oxygenated blood from the heart to the rest of the body

artery a blood vessel that carries blood away from the heart to different parts of the body

atria (singular: **atrium**) the upper chambers of the heart that receive blood from the body or lungs

autotroph an organism that can make its own energy, usually through photosynthesis

bronchi (singular: **bronchus**) tubes formed by the division of the trachea

bronchiole small tubes formed by the division of the bronchi

capillary the narrowest type of blood vessel; capillaries reach nearly every cell of the body

carbon dioxide a gas that animals, including humans, exhale when they breathe out, produced as a result of their body's metabolic processes; also used by plants in photosynthesis

cell the building blocks of all living things

cellular respiration a set of processes in cells that converts chemical energy from nutrients into energy (ATP) that can be used by cells

chloroplast an organelle within a plant cell where photosynthesis takes place

circulatory system the system that carries materials around the body; it consists of the heart, blood vessels and blood

closed circulatory system a circulatory system in which blood is enclosed in vessels and circulates through a complete circuit, starting and ending at the heart

diaphragm a sheet of muscle that separates the chest from the abdomen

digestive system the system in which food is broken down and nutrients absorbed

disease an illness or a sickness that can be characterised by specific signs or symptoms

disorder an illness that disrupts normal physical or mental functions of an organism

dysfunction the impaired or abnormal functioning of a tissue, an organ or a system within the body

ethics a set of principles by which your actions can be judged morally acceptable or unacceptable

excretory system the system in the body that processes and removes waste products

exhalation process of air moving out of the lungs

gill a specialised respiratory organ in aquatic animals such as fish that extracts oxygen from water and releasing carbon dioxide

heterotroph an organism that cannot make its own energy and needs to get energy from other sources, mainly by consuming plants and animals

inhalation the process of air moving into the lungs

lung an organ in the chest cavity where gas exchange occurs

magnetic resonance imaging a medical imagining technique that uses a magnetic field and radio waves to create three-dimensional images

medical imaging techniques to create two- and three-dimensional images of parts of the body, normally used to identify medical problems

multicellular made up of many cells

nasal cavity the hollow space inside the nose that air passes through when breathing, helping to filter, warm, and moisten the air before it reaches the lungs

open circulatory system a circulatory system in which blood is not fully enclosed in vessels and directly bathes tissues; common in invertebrates

organ a structure made up of at least two different types of tissues that work together to complete a function

organ system two or more different organs that work together

organoid artificially grown cells that resemble an organ

oxygen a gas that animals, including humans, breathe in from the air and use to help their bodies produce energy

phloem a plant tissue that carries glucose from the leaves to all other parts of the plant

photosynthesis the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from sunlight

plasma the clear yellowish liquid part of blood that carries blood cells and other substances such as nutrients and wastes

platelet a small cell fragment in blood that helps with clotting to prevent excessive bleeding when there is an injury

pulmonary artery an artery that carries deoxygenated blood from the heart to the lungs

pulmonary vein a vein that brings oxygenated blood from the lungs to the heart

pulse the regular expansion and contraction of the arteries in response to the heartbeat

red blood cell a cell that carries oxygen from the lungs around the body

respiratory system the system of organs and tissues that takes air into the body

root the underground part of a plant that absorbs water and nutrients from the soil

root hair an extension on the outer surface of some root cells that increases the surface area for water absorption

specialised cell a cell that has specific structures to allow it to perform specific functions

stem cell a cell that can develop into different types of cells under specific conditions

stent a small mesh tube that holds passages open in the body

stomata (singular: **stoma**) microscopic holes in the leaves of plants where gases such as oxygen, carbon dioxide and water vapour can enter or exit the plant

system collection of interconnected organs working together for a collective purpose

tissue a group of cells of the same type that carry out the same function in the body

trachea the tube that carries air from the nose and mouth into the chest cavity

tracheid a narrow tube-like cell in xylem tissue

transpiration the passive movement of water through a plant and its evaporation from the leaves

urine the liquid waste product of animals that contains a range of substances, including urea, and which is removed from the blood by the kidneys

valve a structure in the heart and blood vessels that controls the direction of blood flow, preventing backflow

vascular system a system of hollow tubes or vessels that transports water and nutrients around an organism

vein a blood vessel that carries blood to the heart

vena cava the large vein that carries deoxygenated blood from the body to the heart

ventricle one of the lower chambers of the heart that pump blood to the body or lungs

X-ray high-frequency electromagnetic radiation that can penetrate materials

xylem a plant tissue that carries water from the roots to the rest of the plant

TOPIC 3

Classifying matter: Elements, compounds and mixtures



Everything is made of matter. Matter is anything that takes up space and has mass. All matter is made from tiny particles called atoms. Sometimes an atom can join with other atoms to make a molecule.

There are 118 known types of atoms. Elements are made of just one type of atom. These elements make up all matter in the universe. Two or more elements combine to make a compound.

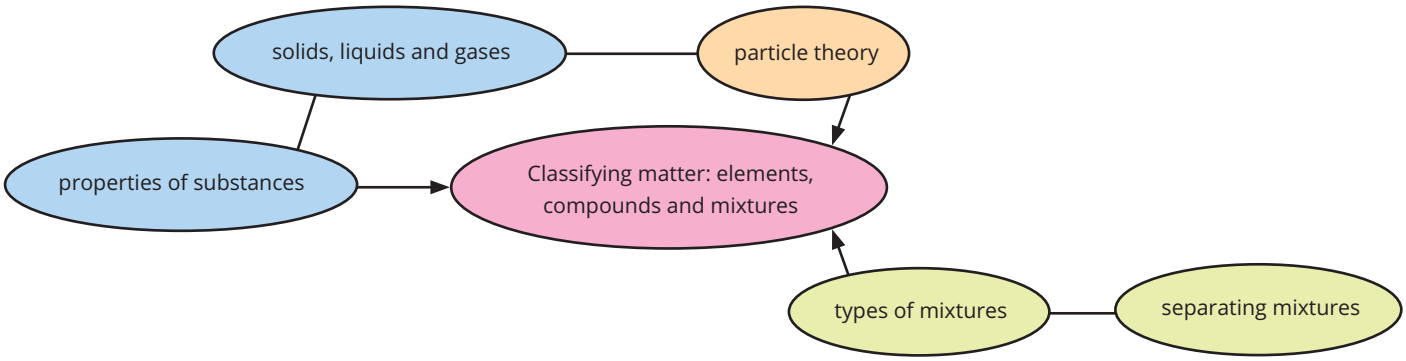
In this topic, you will learn about atoms, molecules, elements and compounds. You will also study mixtures and alloys and learn how to read chemical formulas. You will learn how to name molecular compounds and how to draw particle diagrams.

Learning intentions

- ☐ To understand that elements are made up of only one type of atom **107**
- ☐ To be able to observe, record and organise information of elements **113**
- ☐ To understand the differences between elements and compounds **115**
- ☐ To understand how some gases present in the air were discovered, how they have been used and the implications of their use in society **120**
- ☐ To be able to compare the properties of elements to the properties of compounds **128**
- ☐ To understand the differences between mixtures and pure substances (elements and compounds) **130**
- ☐ To be able to use observable properties to classify elements as metals or non-metals **138**
- ☐ To be able to conduct an experiment that involves the production of a metallic element from a compound **139**
- ☐ To understand that the particles in matter can have different arrangements **141**
- ☐ To understand how chemical formulas of compounds are written **145**
- ☐ To be able to compare information provided in symbols, formulas, two-dimensional models and three-dimensional models of substances **150**
- ☐ To be able to relate the structure of substances to their observable properties **152**

3 Classifying matter: Elements, compounds and mixtures

The key concepts that you will use in this topic:



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

Properties of solids, liquids and gases

1 The three key states of matter are solids, liquids and gases. Name the state(s) that:

- **a** have a fixed shape
- **b** have a definite boundary
- **c** can diffuse quickly
- **d** cannot be compressed.

2 When a ballon is filled with helium gas, it can float upwards in the air. A student suggested that this must be because the helium makes the balloon lighter. State whether you agree with this, explaining the reasons for your answer.

Particle theory

3 All materials are made up of particles. Describe the behaviour of particles in a liquid in terms of their movement, spacing and attractions between particles.

4 Liquefied petroleum gas (LPG) is a fuel used for barbecues and some cars. When released from the cylinder, it turns into a gas. Explain, using the ideas of particle theory, why it is in liquid form when contained in the cylinder.

5 Describe what happens to the particles in a solid when the solid is heated.

Types of mixtures and separating mixtures

6 When salt is added to water and stirred, the salt seems to disappear.

- **a** Using the terms 'solute', 'solvent', 'dissolves' and 'solution', describe what has happened to the salt.
- **b** Describe a way to recover the salt from the water.

7 Air in the atmosphere contains a number of gases, including oxygen, nitrogen, carbon dioxide and helium.

- **a** Which one of these gases do you think is the most abundant in our atmosphere?
- **b** State whether you think the amount of each gas in the atmosphere is fixed or can change. Explain the reasons for your answer.

3.1 Elements, atoms and symbols

Lesson overview

The desk you are sitting at, the pen you are holding, and the clothes you are wearing are all made of matter. Chemistry is the study of matter, and all matter is made up of atoms. Gold, silver, neon and tin are probably all terms you have heard before. Each of these substances is an element. An element is a substance made entirely of one type of atom.

There are 118 elements that have been identified and named, and each has its own unique symbol. Sometimes these symbols are obvious, such as Ne for neon; other times they are less obvious, such as Au for gold. All known elements are represented and organised in the periodic table.

In this lesson, you will learn about atoms and elements. You will learn that atoms make up all matter, that an element is a collection of one type of atom, and that each element has a unique symbol represented on a periodic table.

SC 1 I can explain what an atom is

Learning intention

To understand that elements are made up of only one type of atom

Success criteria

SC 1: I can explain what an atom is.

SC 2: I can recall that elements are made up of only one type of atom.

SC 3: I can state a range of elements and represent them with their symbols.

KEY TERMS

matter a physical substance; anything that has mass and volume

atom the smallest piece of individual matter that can exist by itself

Atoms

Imagine small building blocks making up everything around you. You cannot see them, but they make up all **matter**. Previously, you have learned that matter is anything that has a mass and takes up space. This could be something solid, like a piece of wood, or it could be the air around you.

All matter is made up of **atoms** (Figure 3.1.1). Atom comes from the ancient Greek word 'atomos', which means indivisible. Atoms are the smallest individual pieces of matter that can exist by themselves. Atoms are themselves made up of smaller parts: protons, neutrons and electrons (Figure 3.11). Think of an atom like a grape: there are parts that make up grape (the skin, the flesh, the seed), but for it to be a grape you need all the parts.

You will learn more about the structure and parts of an atom later. Atoms are very small and cannot be seen, even under a microscope. For example, a human hair could fit approximately a million carbon atoms across it.

One way to think about the idea of an atom is to carry out a 'thought experiment'. Imagine a solid, such as a piece of gold, then imagine cutting it in half, then in half again, and again, and again and so on. Eventually you would get to the point that you cannot divide the gold anymore.

This is the point that you have reached one atom of gold.

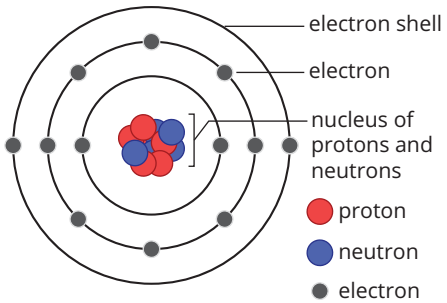


FIGURE 3.1.1 Atoms are too small to see; this is a representation of an atom.

SC 1 CHECK YOUR UNDERSTANDING

The word 'atom' is derived from the Greek word *atomos*, which was used to describe something that cannot be cut up into smaller pieces (is indivisible).

a Explain why this word was chosen to describe the idea of atoms.

b Describe two other characteristics of atoms.

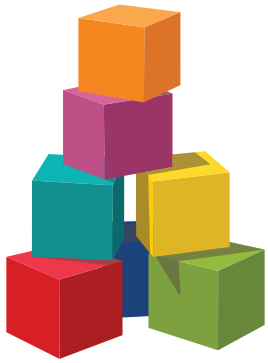


FIGURE 3.1.2 Atoms are like small building blocks that make up all matter.

KEY TERMS

element a substance made up of only one type of atom
allotrope a different form of the same element

SC 2 I can recall that elements are made up of only one type of atom

Atoms and elements

There are different types of atoms. There can be a silver atom, an oxygen atom or a calcium atom. Silver, oxygen and calcium are all examples of elements. An **element** is made up of one type of atom. An element cannot be broken down into other substances. Using the analogy of building blocks, each element is a like a different coloured block (Figure 3.1.2). A big block of red is only made of red 'atoms'.

There are now 118 identified elements. Some elements are common on Earth (e.g. oxygen and carbon), while others only exist briefly in a laboratory. For example, meitnerium is an element with the symbol Mt. It is a synthesised element (which means it is not found in nature). It is named after the Austrian physicist Lise Meitner.

The element carbon

Carbon is an element. Diamond and graphite look very different but are both made entirely of carbon. In diamond and graphite, the atoms are arranged differently.

The arrangement of carbon in diamond and graphite is shown in Figure 3.1.3. The lines represent links (or bonds) between the atoms.

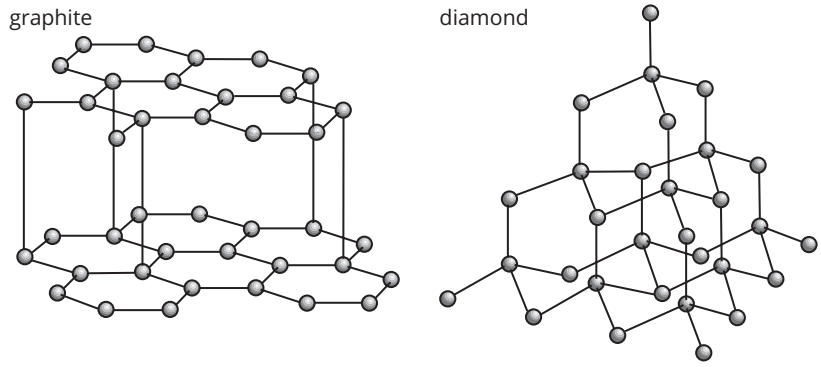


FIGURE 3.1.3 The arrangements of carbon atoms in diamond and graphite

Diamond and graphite are **allotropes**. Allotropes are different forms of the same element (Figure 3.1.4). Both diamond and graphite are carbon, but with the atoms arranged differently.

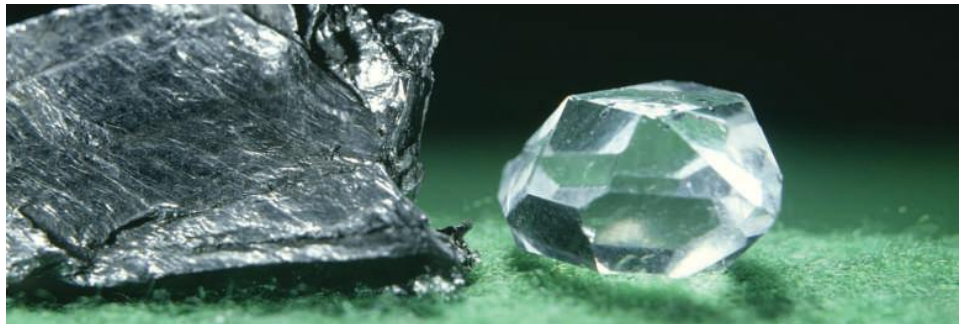


FIGURE 3.1.4 Graphite (left) has very different properties from diamond (right).

Scifile

The element lithium

The element lithium (Li) is sometimes called 'white gold' due its silvery-white colour and its high value. Lithium is used in batteries that will be essential for a successful transition away from burning fossil fuels to sustainable energy supplies, such as solar and wind power.



SCIENCE IN SOCIETY

The value of gold (Au)

You may wonder why the price of gold is so important. In 2024, the price of pure gold (described as 24-carat gold) was around $3600 (AUD) per ounce (1 ounce = 26 grams).

There are many reasons why gold has value.

- Gold has a distinct appearance so it is recognised by many different peoples and cultures around the world.
- Gold can be produced in a very pure form, which means that gold produced in Australia is the same as gold produced anywhere around the world.
- Gold is relatively rare, and expensive to extract from Earth.
- Gold is an unreactive metal, which means it will last for a very long time.
- Gold can be melted and formed into small units, such as ingots and coins, without losing any of the gold itself (Figure 3.1.5).

For these reasons, gold has been used as currency for thousands of years, and continues to be used as a form of 'wealth storage'. For example, the Reserve Bank of Australia owns around 80 tonnes (80 000 kg) of gold.

Despite Australia's strong link with gold mining, the name is not connected. The name Australia is derived from the Latin *Terra Australis* meaning southern land. The symbol Au for gold comes from *aurum*, the Latin name for gold.



FIGURE 3.1.5 The biggest and heaviest gold coin in the world at the Perth Mint, Western Australia, made from 1 tonne of 99.99% pure gold

SC 2 CHECK YOUR UNDERSTANDING

There are thousands of different substances in the world, but only 118 different elements have been discovered. Explain, using the idea of atoms, why this is.

SC 3 I can state a range of elements and represent them with their symbols

Elements and their symbols

All elements have a unique symbol. Some of them seem obvious (e.g. H for hydrogen). Others are not obvious (e.g. Na for sodium). Some have been named after a place (e.g. americium), some have been named after a famous scientist (e.g. mendelevium—Dmitri Mendeleev developed the first periodic table) and some are named from ancient languages (e.g. helium is from the Greek word for sun, *helios*).

Only elements are included on the periodic table.

DISCOVER MORE

A Russian scientist named Dmitri Mendeleev developed an outline of the periodic table in the 1800s. He left gaps where he thought an element would be discovered and, remarkably, those elements were discovered later. This supported his way of organising the elements.

The periodic table

All elements are listed on the periodic table (Figure 3.1.6). Vertical columns are called groups, and horizontal rows are called periods. Periodic means repeating, and each row has similarities to the other rows, which is why the name 'periodic' table is used.

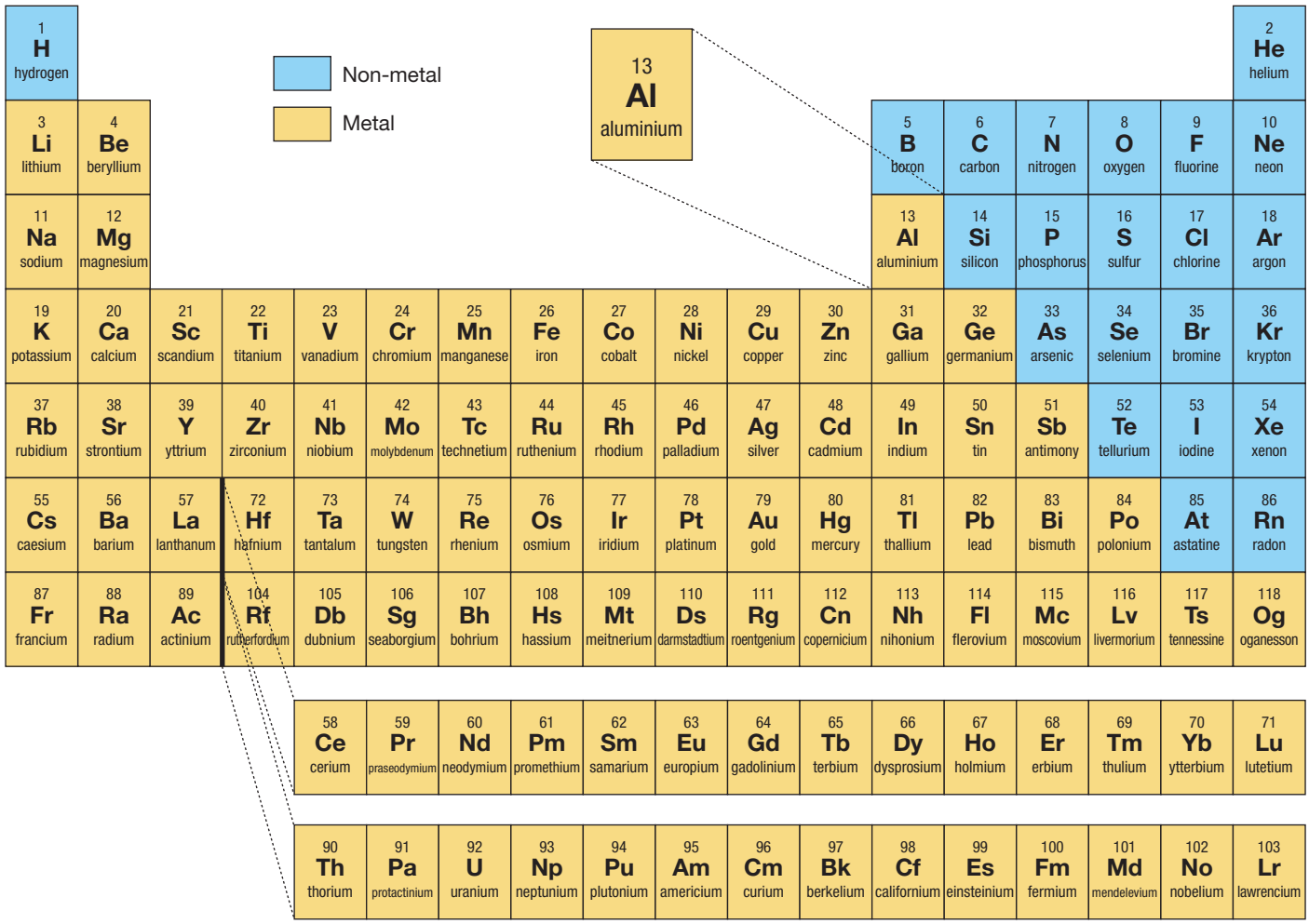


FIGURE 3.1.6 The modern periodic table

Element symbols

Writing element symbols is an important skill that helps you communicate information. Consider the example of the symbol for magnesium.

1. Identify the element on the periodic table. The element is magnesium (Mg).
2. The first letter (M) must be in upper case.
3. If there is more than one letter, the rest must be in lower case.

For magnesium, write Mg (never MG or mg).

New elements

When new elements are discovered in a laboratory, they are given a temporary three-letter symbol. Once the discovery has been confirmed, the element is given its official name and symbol (usually two letters). For example, element 117, previously known as ununseptium (Uus), is now called tennessine (Ts) after the US state of Tennessee (Figure 3.1.7).

What would you name an element if you discovered one?

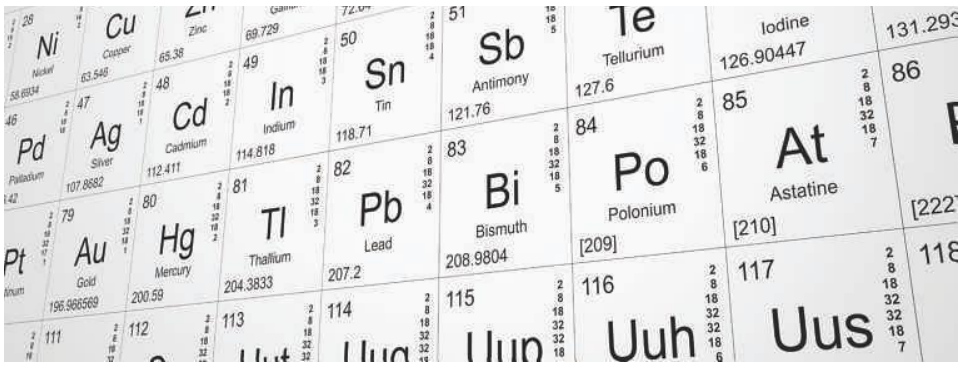


FIGURE 3.1.7 A section of a version of the periodic table showing some three-letter symbols, including ununseptium (element 117)

More elements

Table 3.1.1 provides information about four more common elements: sodium, nickel, iron and copper

TABLE 3.1.1 Four common elements

Element	Symbol	Origin
sodium	Na	Latin (*natrium*)—soda in English
nickel	Ni	From German word *kupfernickel*, meaning devil's copper
iron	Fe	Latin (*ferrum*)
copper	Cu	The Romans first obtained copper on the island of Cyprus. The Latin word for Cyprus is *cuprum*.

SC 3 CHECK YOUR UNDERSTANDING

State the symbols for the following elements.

a helium
b mercury
c gold
d magnesium
e manganese
f iron
g sodium
h chlorine

Lesson review

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

1 Carbon is the element upon which life on Earth is based. Compounds such as DNA, proteins and sugars (a type of carbohydrate) all contain carbon.
- **a** State the chemical symbol of carbon.
- **b** Elements can sometimes exist in forms called allotropes. Use the example of carbon to explain the meaning of the term 'allotrope'.
- **c** Find out what two other elements are present in all carbohydrates.

2 The element mendelevium has the symbol Md and was discovered in 1955.
- **a** Explain why Md was used as the symbol for mendelevium and not Mn.
- **b** Name the scientist whom this element was named after.
- **c** Describe how this scientist contributed to our understanding of atoms and elements.

3 The following words can be spelt by combining chemical symbols. For each word, identify the symbols of the names of the elements used. It would help to have a periodic table to refer to for this question. For example: band = Ba (barium) Nd (neodymium)
- **a** flame
- **b** aspirin
- **c** dynamite

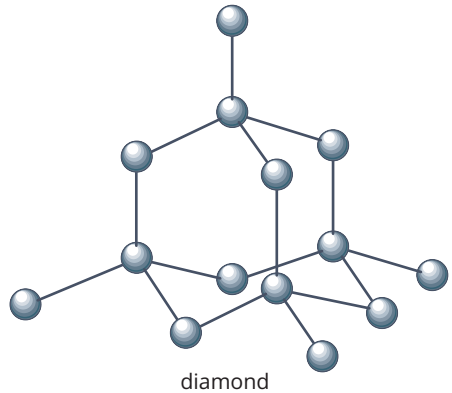
4 Describe the difference between the meanings of the words 'atom' and 'element'.

5 Consider the table below that shows a range of elements and their chemical symbols.

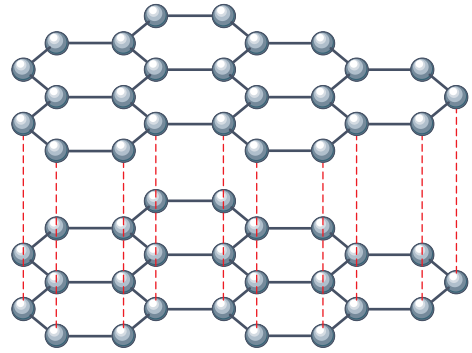
Name	Symbol
copper	Cu
americium	Am
curium	Cm
francium	Fr
sodium	Na
mendelevium	Md

From these elements, state two that:
- **a** are named after places
- **b** are named after people
- **c** have their symbols derived from the Latin names of the elements.

6 Consider the diagram of the structures of diamond and graphite.
- **a** What do the round grey objects represent?
- **b** What do the lines in the diagrams represent?
- **c** Suggest one reason a different arrangement of particles results in different properties in the two allotropes.



diamond



graphite

3.2 Observing and describing elements

Introduction

All elements have properties. A property is a characteristic that can be observed. Maybe they have a high melting point, are a solid at room temperature or conduct electricity. These are some properties of elements (Figure 3.2.1). Elements with similar properties are grouped (vertical columns) in the periodic table.

In this practical investigation, you will investigate the physical and chemical properties of some common elements.

Learning intention

To be able to observe, record and organise information about elements

Success criteria

SC 1: I can describe the observable properties of a range of elements.

SC 2: I can create a table or spreadsheet that organises observations collected from an investigation.

Background

This investigation examines some of the physical and chemical properties of some common elements.

Physical properties to be observed

- State: is it a solid, a liquid or a gas?
- Colour: does it have a distinctive colour?
- Solubility: does it dissolve in water?
- Density: does it sink or float in water?

Chemical property to be observed

Reaction with acid (hydrochloric acid): Is hydrogen gas produced? (Bubbles indicate a gas has been produced.)



FIGURE 3.2.1 Copper is ductile, which means it can be drawn into a wire; this is one of its properties.

Aim

To investigate the physical and chemical properties of some common elements

Materials

- two small pieces of the following elements: copper, iron, aluminium, zinc, tin, magnesium
- matches
- splint
- 12 test tubes and test-tube rack
- hydrochloric acid (1.0 M)
- sandpaper

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

- Wear safety glasses and lab coats/aprons as directed by your teacher.
- Avoid skin contact with acid.
- Take care with sharp edges on the samples of metals.
- Take care with matches because of the possibility of burns.
- Never tip samples down the sink. Follow your teacher's instructions to dispose of them safely.

Method

Read through the method below and then create a suitable results table before conducting the investigation.

1. Put on safety glasses and any other protective equipment as directed by your teacher.
2. Collect all the equipment.
3. Rub each piece of metal with sandpaper (this is to remove any oxide coating).
4. Record the colour of each element in the results table.
5. Label six test tubes and place one piece of each element in each of the test tubes.
6. Cover each sample with a 2 cm depth of water and record observations.
7. Record its density (does it float or sink?).
8. Place a second piece of each sample in a clean test tube.
9. Cover with a 2 cm depth of hydrochloric acid and record your observations in the results table.
10. If any bubbles are observed, place another empty test tube over the opening for 10 seconds and collect any gas produced.
11. Remove the second test tube and trap any gas collected by placing your thumb over the opening, holding the test tube at a 45° angle with the top of the test tube pointing upwards and away from you.
12. Light a splint and hold it to the opening of the upper test tube and record what happens (Figure 3.2.2). If you hear a squeaky 'pop', this indicates hydrogen gas has been produced.
13. Repeat steps 9–12 for the other five elements.

GO TO
Toolkit section 2.1, Reducing risk



FIGURE 3.2.2 Testing for hydrogen gas—a 'squeaky' pop indicates the presence of hydrogen gas.

Results

Design a suitable table for the experiment and record your results. Alternatively, you can create a spreadsheet for your results.

Conclusion

Write your conclusion by answering the following questions.

1. What did all the samples have in common?
2. Why did you rub the samples with sandpaper?
3. How did you know a gas was produced when a sample was placed in hydrochloric acid? How could you determine what gas it was?

Evaluation

Evaluate your practical investigation by answering the following questions.

1. What could you have improved?
2. What other elements would you like to test?
3. For the element(s) you chose for question 2, research their properties. Could they be tested in a school laboratory? Why or why not?

3.3 Elements and compounds

Lesson overview

There are 118 known elements listed on the periodic table but there are millions of different substances that are made from these elements.

A **compound** is a substance made from more than one element. That means it is made of two or more types of atoms. There are many different combinations of elements to make many different compounds.

In this lesson, you will learn about the differences between elements and compounds. You will also learn about compounds that are present in everyday items and how to draw particles in elements and compounds (Figure 3.3.1).

SC 1 I can describe differences between elements and compounds

An element is made up of one type of atom, and each type of atom has a symbol represented on the periodic table. When more than one atom joins together, they create a **molecule**. Oxygen in the air you breathe contains molecules of oxygen, which are two atoms of oxygen joined together.

Often different elements (and, therefore, different types of atoms) are combined to make a compound. That is, compounds always contain more than one type of atom. The acid in your stomach is hydrochloric acid and it is made up of hydrogen and chlorine.

Many compounds are made of molecules, where the atoms are joined together to make the particle that is called a molecule. Sugar, for example, contains atoms of carbon, hydrogen and oxygen joined to form molecules of sugar. Water is a simpler example, containing just the elements hydrogen and oxygen (Figure 3.3.2).

Elements and compounds are both **pure substances**.

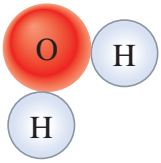


FIGURE 3.3.1 Water is a compound. It contains molecules that consist of two hydrogen atoms and one oxygen atom.



FIGURE 3.3.2 Water is one of the most common compounds. It is made up of hydrogen and oxygen. Its formula is H_2O.

SC 1 CHECK YOUR UNDERSTANDING

A student said that carbon dioxide and oxygen must both be compounds because they contain molecules. Explain why this is incorrect.

Learning intention

To understand the differences between elements and compounds

Success criteria

SC 1: I can describe differences between elements and compounds.

SC 2: I can list many different types of elements and compounds found in everyday items.

SC 3: I can draw diagrams that demonstrate the differences in particle arrangement between elements and compounds.

KEY TERMS

compound a pure substance that is made up of two or more different types of atom chemically joined
molecule a group of atoms joined together with chemical bonds
pure substance a material that is made up of only one type of substance

KEY TERMS

formula a representation of a substance that uses chemical symbols and numbers to show the relative numbers of the atoms present in the substance

inert gas an element in group 18 of the periodic table that does not easily react because it has a full outer electron shell

SC 2 I can list many different types of elements and compounds found in everyday items

Many everyday substances are elements (e.g. copper, tin, neon and oxygen). Elements are made of one type of atom.

Other substances might be compounds. Table salt, sugar, water and ammonia are all examples of compounds. This means they are made of two or more elements. Compounds have a definite formula (this is important when you compare them to mixtures) and are pure substances. Different compounds have different properties and can be represented by a **formula**.

There are 118 elements, and these can combine in different combinations to make compounds. Some elements do not combine with others; they are called **inert gases**. They are listed in the far-right-hand column of the periodic table. Some examples are neon (Ne) and argon (Ar).

Scifile

Formulas

Elements in a compound are held together by chemical bonds. Every element has a unique symbol. In a compound, when the symbols are written together, this is called a formula.

For example, table salt (also known as sodium chloride) is made up of sodium (Na) and chlorine (Cl) atoms. The chemical formula for table salt is NaCl. This means that for every one sodium atom there is one chlorine atom.



Everyday elements

Uranium

Uranium is an element. Its symbol is U. It is mined in Australia for use as a fuel for nuclear energy production in other countries (Figure 3.3.3).



FIGURE 3.3.3 A uranium mine in the Northern Territory

Chlorine

Chlorine is an element. Its symbol is Cl; however, in chlorine gas it exists as molecules of chlorine that have the formula Cl_2. Chlorine is a poisonous yellow-green gas.

Neon

Neon is an element. It is an inert gas, which means it does not combine with other elements to make a compound (Figure 3.3.4).



FIGURE 3.3.4 The neon atoms in this sign cause it to glow when electricity is passed through the neon.

Everyday compounds

Sulfuric acid

Sulfuric acid is a compound (Figure 3.3.5). It contains the elements hydrogen, sulfur and oxygen. Sulfuric acid is a strong acid; it is the acid used in some batteries. Its formula is H_2SO_4.



FIGURE 3.3.5 Huge quantities of sulfuric acid are produced and used in Australia every year.

Carbon dioxide

Carbon dioxide is a compound. It contains the elements carbon (C) and oxygen (O). Its formula is CO_2. Every time you breathe out, you exhale carbon dioxide. It can also be found in some fire extinguishers, and is also what gives fizzy drinks their fizz.

Chlorophyll

Chlorophyll (Figure 3.3.6) is the pigment that makes plants green. It is a large molecule made up of carbon, hydrogen, magnesium, nitrogen and oxygen. Its formula is $C_{55}H_{72}O_5N_4Mg$.



FIGURE 3.3.6 Chlorophyll is a compound that gives plants their green colour.

What are you made of?

Approximately 99% of the human body is made of just six elements: oxygen, hydrogen, nitrogen, carbon, calcium and phosphorus, with 65% being oxygen (Figure 3.3.7).

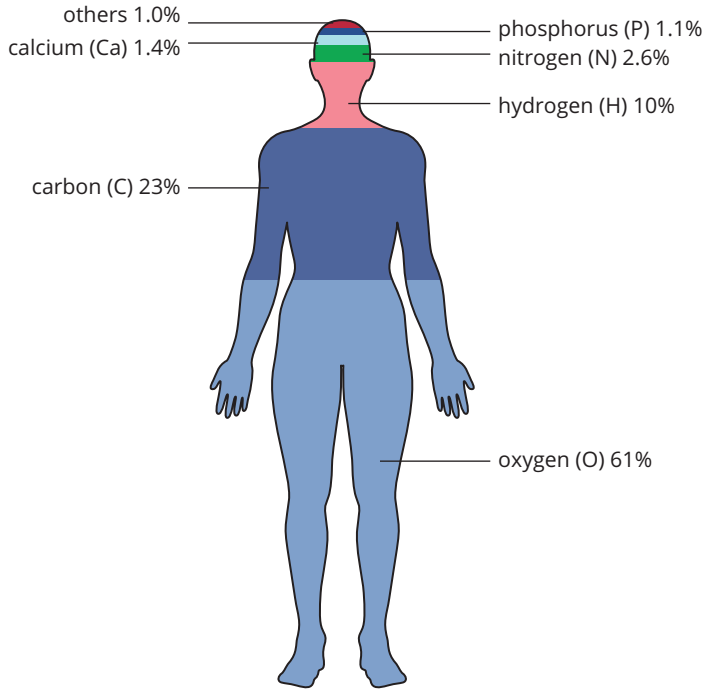


FIGURE 3.3.7 The six main elements in the human body

SC 2 CHECK YOUR UNDERSTANDING

Argon gas is an element that can be used for the packaging of food that stops the food from going bad.

a Suggest why argon can be used for this purpose.

b Name two other elements that behave in a similar way to argon. You may need to use a periodic table to help with this question.

SC 3 I can draw diagrams that demonstrate the differences in particle arrangement between elements and compounds

Representing atoms and molecules

An element is made of one type of atom and may be made up of single atoms or molecules (two or more atoms joined together). A compound is made of two or more different elements joined together and often contains molecules. Diagrams can represent the differences between atoms and molecules and whether the substance containing these particles is an element or a compound.

SkillBuilder

Drawing elements and compounds

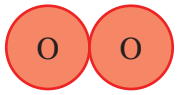
Atoms and molecules can be represented with diagrams.

- Each atom can be a circle.
- Every element will have its own colour/shading to distinguish it from other elements.

- Atoms that are joined (bonded) together should be shown as touching each other.
- Use a key or labels to identify the different elements.

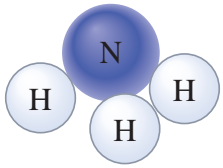
Examples:

1 Noah knows that a molecule of oxygen contains two oxygen atoms bonded together. He represents this as shown here, with each atom labelled with the symbol 'O':



Because there are two atoms in contact with each other, Noah can see it is a molecule.

2 Lottie is asked to draw ammonia; she sees it has one nitrogen and three hydrogens. She represents this as one nitrogen atom coloured blue (labelled with an 'N'), in contact with three hydrogen atoms coloured white, (each labelled with 'H').



SC 3 CHECK YOUR UNDERSTANDING

Methane has the formula CH_4. Carbon can bond with four other atoms, but hydrogen can only bond with one other atom. Draw a labelled representation of a molecule of methane.

Lesson review

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

1 Read the following statements about elements and compounds. Rewrite any that are wrong to make them correct.
- **a** Compounds are not pure substances because they contain more than one element.
- **b** Compounds do not contain atoms.
- **c** All elements are made up of individual atoms that are not joined together.

2 Oxygen gas has the formula O_2.
- **a** Describe the particles that exist in a sample of pure oxygen.
- **b** Water is a compound that contains oxygen. Describe the particles present in pure water.
- **c** Name three other compounds that contain oxygen.

3 Carbon tetrachloride is a compound that is made of molecules that each contain one carbon atom and four chlorine (Cl) atoms atoms. Draw a labelled representation of a molecule of carbon tetrachloride.

4 Air is a mixture that contains a number of gases, including O_2, N_2, CO_2 and Ar.
- **a** Using these examples, explain the difference between elements and compounds.
- **b** Using Ar and N_2, explain the difference between atoms and molecules.
- **c** Explain why air cannot be described as a compound.

3.4 The use of gases from the air

Learning intention

To understand how some gases present in the air were discovered, how they have been used and the implications of their use in society

Success criteria

SC 1: I can describe how the understanding of gases in the air changed as a result of scientific investigation.

SC 2: I can describe how carbon dioxide is used to carbonate water and how this has influenced society.

SC 3: I can describe how oxygen can be separated from air and how oxygen can be used in a range of situations.



FIGURE 3.4.2 The *vãyu mudrã* hand gesture, used in yoga to regulate the 'air element' of the body



FIGURE 3.4.3 The Japanese kanji character for wind

Lesson overview

Air is a mixture of gases. Some of these gases are elements, such as oxygen (O_2) and nitrogen (N_2), and some are compounds, such as carbon dioxide (CO_2). Air is about 78% nitrogen and 21% oxygen (Figure 3.4.1). Carbon dioxide is a tiny percentage of the air (0.04%), but changes to the percentage of carbon dioxide in the air are having major effects on the climate.

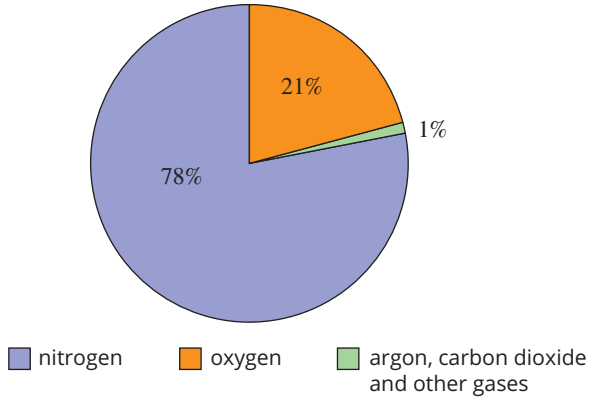


FIGURE 3.4.1 The approximate composition of air in the atmosphere

Gases

Gases such as oxygen and carbon dioxide have a wide range of uses in areas such as food and drink, and health care.

In this lesson, you will learn about how scientists, including Joseph Priestley, discovered more about the gases in the air. You will learn about how some of these gases have been used, and how they have affected society.

SC 1 I can describe how the understanding of gases in the air changed as a result of scientific investigation

Gases in the air

In many ancient cultures, air was considered one of the key 'elements' of the world.

Hindu teachings include the five elements of earth (*prithi*), water (*ap*), air (*vãyu*), fire (*agni*) and aether (*akasha*) (Figure 3.4.2).

Ancient Japanese culture also had five basic substances that were thought to make up everything: earth, water, wind, fire and heaven (Figure 3.4.3).

Today, the word 'element' is used in science to describe substances that contain only one type of atom. Air is a mixture of compounds such as carbon dioxide (CO_2) and water vapour (H_2O) and elements such as oxygen (O_2) nitrogen (N_2) and argon (Ar).

Investigating the nature of air

The nature of air and the gases that it contains has only really been fully understood in the last few hundred years. In the seventeenth century, all substances that burned in air were thought to contain an element called phlogiston, which was released when the 'element' burned in air. When the air was full of phlogiston, it became phlogisticated, and could no longer allow things to burn in it. Phlogiston was given a symbol (Figure 3.4.4) by alchemists, scientists who aimed to purify certain materials.

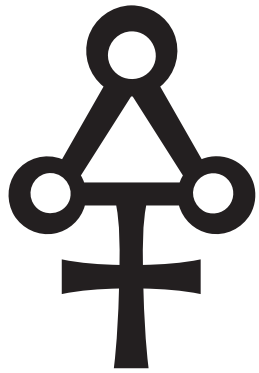


FIGURE 3.4.4 The symbol used for phlogiston in the alchemy alphabet

This theory matched observations at the time, because when objects burned in a fixed amount of air, the material stopped burning after a while, even though there was still plenty of air present.

As more was known about the components of the air, the phlogiston theory was challenged, and eventually replaced with better theories about the composition of the air. The practice of alchemy also evolved and played an important role in the development of modern chemistry and medicine.

Discovering gases in the air

Carbon dioxide

Carbon dioxide was discovered by chemist Jan Baptist van Helmont in 1640. The investigation tested the hypothesis that the products of combustion (burning) would not weigh the same as the starting materials. When he weighed the ash produced from burning charcoal, he discovered that it weighed less than the original charcoal (Figure 3.4.5).

He proposed that this missing mass was because an invisible substance had been produced.



FIGURE 3.4.5 Burning charcoal (an impure form of carbon) produces a gas, now known as carbon dioxide.



FIGURE 3.4.6 The gas left over when a candle has burned in a bell jar is mainly nitrogen.

Nitrogen

The Scottish scientist Daniel Rutherford is credited with the discovery of nitrogen in 1772, but at the time he did not recognise it to be an element. He investigated air that had a candle burning in it (Figure 3.4.6). (Scientists now know that this would have removed all the oxygen.)

He removed the carbon dioxide from the remaining air and the gas left was nitrogen, although the word nitrogen was not used for another 20 years. Many other scientists were also working on isolating this gas, including Joseph Priestley, who called it phlogisticated air.

Oxygen

There are many competing claims between scientists for the discovery of oxygen, including Swedish pharmacist Carl Wilhelm Scheele and French chemist Antoine Laurent Lavoisier. But Englishman Joseph Priestley is normally credited for the discovery, partly because his scientific papers were published in 1775 before Scheele's findings were made public.

Priestley was investigating the substances produced when he focused beams of sunlight on solid mercury oxide and collected the gas produced.

He found that the gas produced made things burn brighter, that mice lived longer in it, and he even felt he had more energy when he breathed the new gas himself (Figure 3.4.7).



FIGURE 3.4.7 Charcoal burning brightly in a flow of oxygen gas

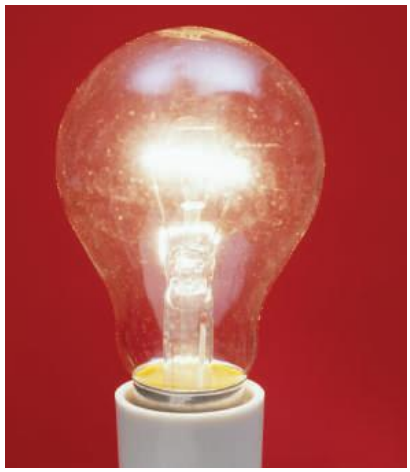


FIGURE 3.4.8 Argon is the gas used inside incandescent light globes because it does not react with the hot, glowing element

Argon

In 1785, Henry Cavendish suspected that there was an inactive gas that made up a small proportion of the air. In 1894, Lord Rayleigh and Sir William Ramsay (using some of Cavendish's old equipment) successfully removed oxygen, water vapour, nitrogen and carbon dioxide from air. After this, there was still some gas remaining, which was named argon, from a Greek word meaning 'inactive' or 'lazy' (Figure 3.4.8).

SC 1 CHECK YOUR UNDERSTANDING

To identify the gases in air, some gases need to be removed. Suggest why it is easier to remove oxygen than argon from air.

SC 2 I can describe how carbon dioxide is used to carbonate water and how this has influenced society

Carbon dioxide and carbonated water

The history of carbonated water goes back to ancient times when natural mineral springs containing carbon dioxide were discovered (Figure 3.4.9). These springs were known for their therapeutic properties, and people believed that drinking the water from these springs could cure a variety of illnesses.

However, it wasn't until the late 1700s that scientists began to understand the science behind carbonation.



FIGURE 3.4.9 Naturally carbonated mineral water rising from the ground in the mountains

Joseph Priestley and gases

Joseph Priestley was an eighteenth-century English scientist and theologian who is credited with discovering the method of infusing water with carbon dioxide (Figure 3.4.10). In the 1700s, people knew that there was gas in the air, but they did not yet understand what it was or how to use it.

Priestley became interested in this gas and conducted a series of experiments to investigate its properties.



FIGURE 3.4.10 A portrait of Dr Joseph Priestley 1733–1804—English chemist, natural philosopher and political writer

The chemistry of carbonated water

Joseph Priestley's discovery of the method of infusing water with carbon dioxide was significant for several reasons. Water with carbon dioxide dissolved in it is not only 'fizzy' but is also more **acidic** than pure water.

This process is an example of a chemical change, where the carbon dioxide gas dissolves in the water and creates to create a new compound with different properties. The acid that is formed is called carbonic acid.

KEY TERMS

acidic having the properties of an acid, or containing acid; having a pH of less than 7

fermentation the chemical process in which carbohydrate or sugar is broken down into a simpler substance, such as alcohol or an acid

The development and use of carbonated water

The history of carbonated water can be traced back almost 400 years (Figure 3.4.11).

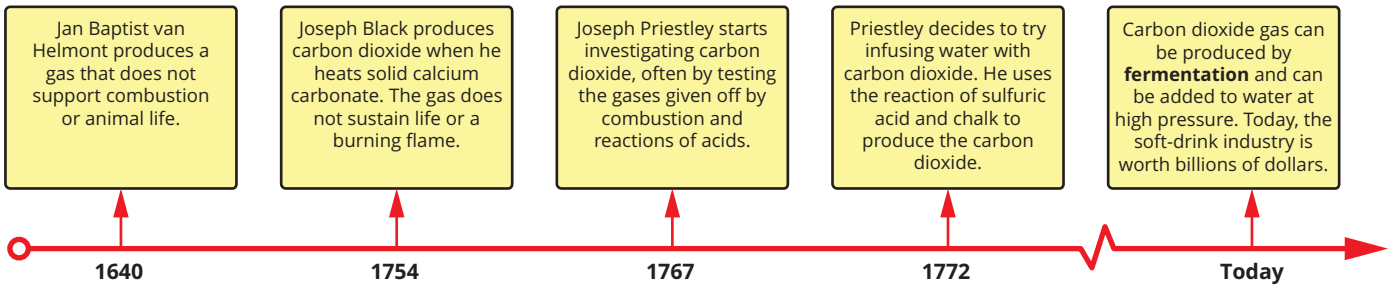


FIGURE 3.4.11 Timeline of the development and use of carbonated water



FIGURE 3.4.12 The addition of carbon dioxide changes the properties of the water.

The modern process of dissolving carbon dioxide in water is similar to the technique used by Joseph Priestley in 1772. However, by increasing the pressure, more carbon dioxide can be absorbed by the water more quickly (Figure 3.4.12). The carbon dioxide is produced, normally as a product of burning fuels, and stored in pressurised cylinders until used. In Priestley's experiment, the carbon dioxide was produced by a chemical reaction between sulfuric acid and chalk (calcium carbonate).

SCIENCE IN SOCIETY

The impacts of carbonated water

The discovery of carbonated water had an effect in the scientific world, but it also had significant impacts on the behaviour of people in society.

Soda

The production of soft drinks using carbonated water started around 250 years ago. Many versions of carbonated water drinks contained sodium compounds such as sodium chloride (table salt), sodium bicarbonate (bicarbonate of soda) and sodium citrate. This is why these drinks were referred to, especially in the United States, as 'soda' (Figure 3.4.13).



FIGURE 3.4.13 Club soda—carbonated water with additional minerals added

These substances were added as preservatives and to balance the acidity of the drink, therefore improving the taste. Most soft drinks contain carbonated water, a sweetener and a flavouring, depending on the drink.

The soft-drink industry

Today the global soft-drink industry makes a profit of $50 billion each year (Figure 3.4.14). The average yearly consumption of soft drinks in Australia is about 100 litres per person. (In the USA it is about 200 litres, and in Japan it is about 20 litres.) In most places in the world, the consumption of carbonated soft drinks is decreasing.

These numbers have implications for society. In the United Kingdom, it has been estimated that about 5% of all litter is Coca-Cola cans. Health risks of soft drinks are well known, including increased occurrence of obesity, tooth decay and risk of cancer.



FIGURE 3.4.14 Our enjoyment of soft drinks brings with it risks to health and the environment.

SC 2 CHECK YOUR UNDERSTANDING

Carbonated water is produced by combining carbon dioxide gas with water.

a State three ways that carbon dioxide can be produced for this process.
b Describe how the carbon dioxide is combined with the water.
c Explain how the properties of water are affected by the addition of carbon dioxide.

SC 3 I can describe how oxygen can be separated from air and how oxygen can be used in a range of situations

Oxygen gas

Oxygen is the most abundant element on Earth and the third most abundant element in the universe. It is a reactive gas that allows things to burn and is essential for animal life on Earth. Oxygen was discovered by Carl Wilhelm Scheele and Joseph Priestley around 1773–1775, but it was Antoine Lavoiser, the person often described as the founder of modern chemistry, who first recognised it as an element and gave it the name 'oxygen'. The name came from the Greek *oxy-gene*, meaning 'acid-producer', which was a misconception. At the time Lavoisier thought that the element oxygen was present in all acids, which is now known not to be true.



FIGURE 3.4.15 Oxygen is a vital component of the atmosphere.

Oxygen in the environment

Oxygen makes up just under 21% of the air. The air we breathe out only contains 17% oxygen because some of the oxygen has been converted to carbon dioxide by the process of **cellular respiration**.

Plants convert carbon dioxide into oxygen through a process called **photosynthesis**.

Before life evolved on Earth, there was virtually no oxygen in the atmosphere (Figure 3.4.15). It was only the presence of plants that increased the amount of oxygen. This includes plants that live in rivers and oceans.

Oxygen is **soluble** in water so some of the oxygen on Earth is dissolved in oceans. 1000 L of seawater contains about 8 grams of oxygen.

KEY TERMS

cellular respiration a set of processes in cells that convert chemical energy from nutrients into energy used by cells
photosynthesis the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from the Sun
soluble able to dissolve in a particular solvent
distillation a process in which evaporation followed by condensation recovers solvents from mixtures

Producing oxygen

The main way of producing oxygen today is by a form of **distillation**. Air, which is a mixture of gases, is cooled to extremely low temperatures (about –200°C) to produce liquid air.

The air is then allowed to warm up and the liquefied gases turn back into gas as they evaporate. The boiling points of the three main components of air are:

- oxygen (–183°C)
- argon (–186°C)
- nitrogen (–196°C).

Because nitrogen and argon have lower boiling points than oxygen, they will turn to a gas first, so they can be separated from the liquid oxygen.

Oxygen is normally stored as a liquid (in pressurised cylinders) because it takes up less space as a liquid than as a gas (Figure 3.4.16).



FIGURE 3.4.16 Oxygen stored as a liquid in pressurised cylinders

SCIENCE IN SOCIETY

Oxygen changing lives

Here are some examples of the uses of oxygen.

Medicine

Oxygen-based therapies are used to treat diseases such as asthma and pneumonia (Figure 3.4.17). Oxygen is also used in emergency situations such as respiratory failure or carbon monoxide poisoning. The oxygen is delivered through a face mask. Some of these treatments occur in a patient's home due to improvements in technology that have reduced the size and cost of the equipment.



FIGURE 3.4.17 A patient at home with an oxygen supply to aid with breathing

Exploration

Oxygen is used in space exploration to improve the power in a rocket engine as the rocket fuel will burn more violently in pure oxygen compared to air. It is also used to provide life support for astronauts in space. Scuba divers use oxygen-rich air in scuba tanks that enable them to explore oceans (Figure 3.4.18).



FIGURE 3.4.18 Oxygen in scuba tanks allows divers to spend extended times under water.

Environmental management

Aerobic bacteria require oxygen to survive. Some aerobic bacteria can be used to break down organic pollutants, such as sewage, in the environment (Figure 3.4.19). Oxygen is supplied to the bacteria to speed up their growth and reproduction rate, which improves the effectiveness of the waste treatment process. Oxygen is also used to produce ozone (O_3), which has a wide variety of uses, including water purification.



FIGURE 3.4.19 Scientists checking the oxygen content in waste water

SC 3 CHECK YOUR UNDERSTANDING

Oxygen is used in the process of cellular respiration.

a Describe what happens during cellular respiration.

b State two applications of oxygen that rely on its role in the process of respiration.

c For one of the situations stated in part b, explain why oxygen is required.

Lesson review

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

1 When Joseph Priestley produced a new gas by heating solid mercury oxide, mice were found to live longer in an atmosphere rich in this new gas. Explain this finding.

2 Describe how adding carbon dioxide to water changed the drinks industry.

3 Describe how modern methods enable carbon dioxide to be combined with drinks quickly to increase the rate of production of soft drinks.

4 Oxygen can be used to treat a range of diseases and emergency situations.

- **a** Explain why asthma sufferers might sometimes need to breathe pure oxygen or air rich in oxygen to reduce their symptoms of the disease.
- **b** Explain why firefighters might need to use oxygen breathing apparatus when tackling an intense fire.

5 The boiling point of oxygen is −183°C and the boiling point for nitrogen is −196°C. Use this information to explain, using correct scientific terms, why distillation can be used to separate oxygen from nitrogen in a sample of air that has been cooled to −200°C.

6 The table shows the approximate relative amounts of different gases in the atmosphere today compared to Earth's early atmosphere.

	Today	Early atmosphere
nitrogen	high (78%)	low
oxygen	moderate (21%)	very low
argon	low (1%)	low
carbon dioxide	very low (0.04%)	high
methane	minimal (0.000 17%)	high

- **a** Briefly summarise the key changes to the atmosphere over time.
- **b** Explain why the amount of oxygen has increased over time.
- **c** Suggest why carbon dioxide is an important part of the atmosphere even though the concentration in air is very low.

3.5 Properties of elements and compounds

Learning intention

To be able to compare the properties of elements to the properties of compounds

Success criteria

SC 1: I can identify the elements present in a range of compounds.

SC 2: I can compare the properties of elements with the properties of the compounds made from those elements.

Introduction

Today we know about the existence of almost 120 chemical elements. Combinations of these make up millions of different compounds. Each element has its own properties. When an element exists in a compound it can have very different properties.

In this practical investigation you will identify the elements in compounds by examining their formulas and investigate the properties of the elements and the properties of compounds made from those elements.

Background

Every element has a symbol represented on the periodic table. Compounds are made of two or more elements chemically combined and are represented by a formula. Every element has physical and chemical **properties**.

Every compound also has properties that may be very different from the properties of the elements in it.

Aim

To compare the properties of elements with the properties of compounds that contain these elements

KEY TERM

property an observable characteristic of a substance; what a substance looks like and how it behaves

Materials

For observation:

- clean iron nail (not galvanised), graphite (carbon) rod, rusty iron nails, photograph of sodium metal, photograph of chlorine gas

For experimentation:

- table sugar (sucrose), table salt (sodium chloride), iron(III) oxide
- sandpaper
- 250 mL beaker
- spatula
- stirring rod

SAFETY NOTES

- Do not taste any of the substances.
- Be careful with sharp ends of nails.
- Wear safety glasses when testing the solubility of the substances.

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. Add the names of the elements in each compound to your results tables.
2. Collect all materials and equipment required.
3. Record the state, colour and texture of all substances in your results tables. Some have been completed for you as they are difficult to observe directly.
4. Place the graphite rod and the iron nail in some water in a beaker to see if they dissolve.

5 Place a small spatula of sugar in 100 mL of water in the beaker and stir with the stirring rod. Record the solubility of the sugar.

6 Repeat step 5 with the salt and then the iron oxide (rust).

Results

Create two results tables like these in your notebook.

Compounds

Substance	Formula	Elements present	State	Colour	Texture	Solubility (does it dissolve in water)
sugar (sucrose)	$C_{12}H_{22}O_{11}$					
table salt (sodium chloride)	NaCl					
rust (iron oxide)	Fe_2O_3					

Elements

Substance	Symbol	State	Colour	Texture	Solubility (how well it dissolves in water)
carbon (graphite)					
hydrogen					insoluble
oxygen					slightly soluble
sodium				soft metal	reacts violently with water (to produce hydrogen gas)
chlorine					slightly soluble
iron					

Conclusion

1 Using an example from this experiment, define the term 'compound'.

2 Using specific examples from your observations, describe the differences between properties of the three compounds in this experiment and the properties of the elements that make up the compounds.

3 Suggest a reason the properties of an element change when it forms compounds.

4 Describe another example where an element's properties vary greatly from a compound that contains that element.

Evaluation

Evaluate your practical investigation by answering the following questions.

1 What did you find challenging about this practical investigation?

2 Describe two ways that practical investigation could be improved.

3.6 Mixtures and compounds

Learning intention

To understand the differences between mixtures and pure substances (elements and compounds)

Success criteria

SC 1: I can describe mixtures as substances that can be separated into pure substances.

SC 2: I can list a range of different types of mixtures and pure substances found in everyday items.

SC 3: I can draw diagrams that demonstrate the differences in particle arrangement between mixtures and pure substances.

Lesson overview

Mixtures are combinations of different pure substances (Figure 3.6.1). These substances can be either elements or compounds. As you have learnt, mixtures can be separated back into pure substances.

In science, 'pure' means that only one thing, or substance, is present. This is true for elements and compounds, so these are called pure substances.

In this lesson, you will re-visit mixtures and how they can be separated into pure substances. You will learn how to tell the difference between mixtures and pure substances. This will include comparing particle diagrams that represent mixtures to particle diagrams that represent elements and compounds.



FIGURE 3.6.1 Cement is an example of a mixture.

SC 1 I can describe mixtures as substances that can be separated into pure substances

Mixtures

Orange juice, muesli and strawberry jam all have something in common. They can all be eaten for breakfast, but they are also all examples of mixtures (Figure 3.6.2). While a compound is two or more elements chemically combined, a mixture contains two or more substances that are not chemically combined.

A mixture can be separated into two or more pure substances by different separation techniques.



FIGURE 3.6.2 Muesli is an example of a mixture; it contains more than one substance, but they are not chemically combined.

Separating mixtures

Filtration

Filtration uses a filter to separate substances based on particle size (Figure 3.6.3).



FIGURE 3.6.3 Filtration separates solid particles from a liquid.

Magnets

A magnet can be used to separate magnetic substances from non-magnetic ones (Figure 3.6.4).



FIGURE 3.6.4 A magnet being used to separate iron filings from yellow solid sulfur

Chromatography

Chromatography is used to separate liquids with different levels of solubility; for example, it can separate mixtures of coloured substances (Figure 3.6.5).



FIGURE 3.6.5 Chromatography can be used to separate different coloured pigments that make up the ink in a marker pen.

Evaporation

Evaporation separates a solute from a solution by boiling or evaporating the solvent (often water) until only the solute remains. For example, salt water can be evaporated until only the salt crystals remain (Figure 3.6.6).

Note that salt water is made of two pure substances: salt (sodium chloride, NaCl) and water (H_2O). In salt water, the salt and water are not chemically combined so the water can be evaporated to leave behind the salt crystals. Salt water does not have a fixed amount of salt in it, whereas pure substances such as salt (NaCl) and water (H_2O) have fixed ratios of the numbers of each type of atom.



FIGURE 3.6.6 Evaporation of salt water leaves the salt crystals behind.

Distillation

Distillation separates liquids on the basis of their different boiling points. For example, different fuels such as petrol and diesel may be separated from crude oil in oil refineries (Figure 3.6.7).



FIGURE 3.6.7 An oil refinery separates crude oil into products such as petrol and diesel by distillation.

SCIENCE IN SOCIETY

'Pure' drinking water and LifeStraw®

Drinking water is not a pure substance. It contains a range of minerals and other dissolved substances. But when those substances are potentially toxic, such as bacteria and parasites, the water becomes unsafe to drink.

This often what happens in the aftermath of a natural disaster such as an earthquake or extreme weather event.

LifeStraw is a water filtration device designed to make contaminated water safe to drink (Figure 3.6.8).



FIGURE 3.6.8 LifeStraw is a portable water purifier that removes almost all bacteria from water.

The LifeStraw works by using advanced microfiltration technology to remove bacteria, parasites and other harmful contaminants from water.

LifeStraw filters are lightweight, portable and require no batteries or electricity.

Lifestraw was originally created for use in emergencies and by people in developing countries who don't have access to clean water (Figure 3.6.9).



FIGURE 3.6.9 A Lifestraw (the blue component) used in a system that provides safe drinking water in a remote area, such as here in Swaziland, Africa, away from any power supply

After a devastating earthquake in Haiti in 2010, clean drinking water became scarce. LifeStraw filters were distributed to help prevent waterborne diseases like cholera. These filters provided immediate access to safe drinking water for thousands of people.

The 2015 Nepal earthquakes left many communities without access to clean water. LifeStraw filters were deployed to provide safe drinking water to people living in temporary shelters and remote areas, ensuring they had a reliable source of clean water (Figure 3.6.10).



FIGURE 3.6.10 The supply of safe drinking water was a major problem following the 2015 Nepal earthquake.

SC 1 CHECK YOUR UNDERSTANDING

Explain how a mixture of sand and salt can be separated into its pure substances.

SC 2 I can list a range of different types of mixtures and pure substances found in everyday items

Types of mixtures

Sugar, muddy water, copper and apple juice are all examples of matter. All matter is either a pure substance or a mixture.

Pure substances can then be categorised into compounds or elements. Sugar (compound) and copper (element) are examples of pure substances. Muddy water and apple juice are examples of mixtures.

Mixtures can then be categorised into **homogeneous mixtures** (or solutions) or **heterogeneous mixtures** (Figure 3.6.11).

KEY TERMS

homogeneous mixture a mixture that has uniform composition and properties throughout

heterogeneous mixture a mixture that varies in composition and properties throughout

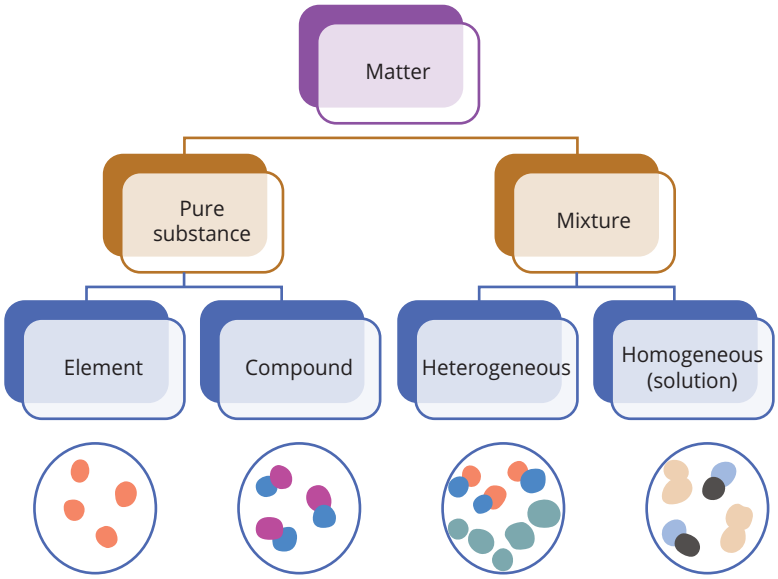


FIGURE 3.6.11 A flow chart for classifying matter

DISCOVER MORE

Look at the start of each word. In homogeneous, homo- means same. In heterogeneous, hetero- means different or other.

Homogeneous mixtures

A homogeneous mixture is one in which the different parts (such as salt dissolved in water) have been uniformly combined (salt water).

This means that a homogeneous mixture appears the same throughout the substance, like clear apple juice (Figure 3.6.12).



FIGURE 3.6.12 This apple juice is an example of a homogeneous mixture.

Heterogeneous mixtures

In a heterogeneous mixture, the parts are not uniformly combined, and the amount of each substance might be different throughout. Think of a chocolate chip biscuit: one part of the biscuit might have lots of chocolate chips while another part might not. A chocolate chip biscuit is an example of a heterogeneous mixture.

Scifile

Alloys: Solutions of metals

When you melt metals, they can dissolve into each other. The mixture that is made is called an alloy. When metal atoms in an alloy have a similar size, such as zinc and copper, they pack together to form malleable alloys, which are relatively soft, such as brass. When the atoms are different sizes, the smaller atoms can fit into the gaps between the larger atoms. These types of alloys, such as steel, are much harder.

This means that a heterogeneous mixture is not the same throughout, like muddy water (Figure 3.6.13).



FIGURE 3.6.13 Muddy water in a river is a heterogeneous mixture.

SC 2 CHECK YOUR UNDERSTANDING

List three examples of mixtures and three examples of pure substances that you might find in a kitchen.

SC 3 I can draw diagrams that demonstrate the differences in particle arrangement between mixtures and pure substances

Comparing particle arrangements of mixtures and pure substances

Particle diagrams can be used to represent state of matter of substances (solids, liquids and gases) (Figure 3.6.14).

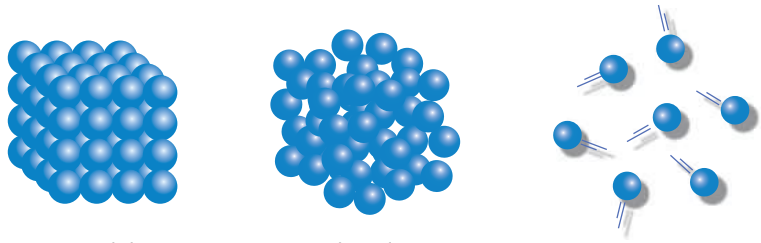


FIGURE 3.6.14 Particle diagram showing the three states of matter

Particle diagrams can also be used to represent elements, compounds and mixtures.

Pure substances

Pure substances (elements and compounds) have definite compositions. For example, water (H_2O), a compound, always has two hydrogen atoms and one oxygen atom. Carbon monoxide (CO) always has one carbon and one oxygen atom (Figure 3.6.15).

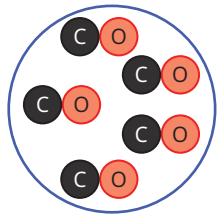


FIGURE 3.6.15 Carbon monoxide is a compound and, therefore, a pure substance; a molecule of carbon monoxide is one atom of carbon and one atom of oxygen joined together.

Mixtures

Mixtures on the other hand do not have a definite composition as seen in these examples.

Air

Air is a mixture of nitrogen gas 78%, oxygen gas 21%, argon 0.9%, carbon dioxide 0.04% and traces of water.

If there is more pollution from burning fossil fuels, there may be more carbon dioxide. The air that you breathe out contains more carbon dioxide and less oxygen than the air that you breathe in. Air is a mixture and does not have a fixed composition.

Salt water

Another example of a mixture is a glass of salt water. There may be one spoonful of salt in the water or there might be three. Both examples are still salt water but there is no set composition for how much salt must be in the water.

Water has a set composition and so does salt (one sodium and one chlorine atom). Water and salt are examples of pure substances. Salt water is a mixture and, with the correct separation techniques, it can be separated into water and salt.

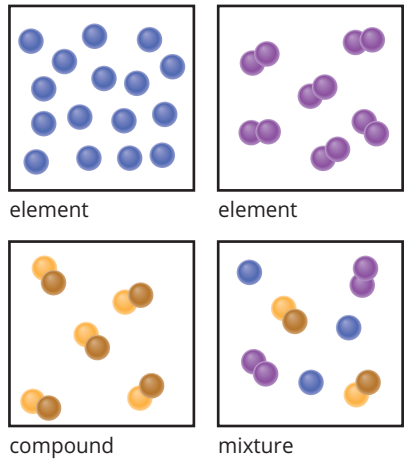


FIGURE 3.6.16 Different ways to represent elements, compounds and mixtures

Particle diagrams summary

The diagrams in Figure 3.6.16 summarise ways to represent elements, compounds and mixtures using particle diagrams.

SC 3 CHECK YOUR UNDERSTANDING

Draw three labelled particle diagrams that represent:

a pure water (H_2O)
b pure oxygen (O_2) gas
c oxygen dissolved in water.

Lesson review

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

1 Describe and explain the process of separating a mixture of iron filings and sulfur powder.

2 Identify the following as a mixture or a pure substance.
- **a** air
- **b** gold (Au)
- **c** muddy water
- **d** baking soda ($NaHCO_3$)

3 Explain why apple juice can be considered a mixture but copper wire is considered a pure substance.

4 Draw and compare particle diagrams for pure water and a solution of sugar. Explain the differences in particle arrangements. You can use a simple representation of the molecules without showing individual atoms.

3.7 Metals and non-metals

Learning intention

To be able to use observable properties to classify elements as metals or non-metals

Success criteria

SC 1: I can identify substances as metals based on their observable physical properties.

SC 2: I can use the names and the position of elements in the periodic table to predict whether they are metals or non-metals.

SC 3: I can explain, with an example, the difference between a pure metal and an alloy.

KEY TERMS

metal an element that is shiny, conducts heat and electricity, and can be hammered into sheets and drawn into wires
malleable able to be hammered or bent into new shapes
ductile able to be stretched to form a wire
lustrous shines when polished or freshly cut
corrosion the breakdown of metals due to their reaction with other chemicals

Introduction

Why do you think electrical wires are made of copper? What about a saucepan being made of stainless steel or aluminium?

What it is about these substances that make them suitable for these uses?

The answer to the last question is based on what properties the substances have. Some groups of substances, such as **metals**, have special properties that only they have.

In this practical investigation, you will observe some chemical and physical properties of various materials that include elements, mixtures and compounds and use this to help classify them as metals or non-metals.

Background

Metals

Metals have certain properties. They are **malleable**, **ductile** and **lustrous** and can conduct electricity.

This practical investigation will examine a range of materials (metals and non-metals) and test their properties.

Alloys

An alloy is a homogeneous mixture of substances, including at least one metal. For example, stainless steel is a mixture of iron, carbon and chromium, and bronze is a mixture of copper and tin.

Alloys have similar properties to metals. By combining the metals, the properties can be changed to make the alloy better for a particular use. For example, to make the metal solid softer, or harder (e.g. in coins) or to make the substance more resistant to **corrosion** (e.g. in saucepans).

Alloys are not compounds. A compound has a fixed ratio of elements, but an alloy does not, which makes it a mixture. An example of an alloy is brass (Figure 3.7.1).



FIGURE 3.7.1 A brass trumpet. Brass is an alloy of copper and zinc.

Aim

To investigate common properties of various substances and classify them as metals or non-metals

Materials

- alligator clips
- electric leads
- sandpaper
- battery pack or powerpack
- globe (or ammeter/multimeter)
- copy of the periodic table
- samples to test: iron nail, stainless steel nail, copper strip, magnesium strip, piece of chalk, plastic, brass tacks, wood, graphite rod

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

- Keep any electrical equipment away from water.

Method

Use this method for each sample.

1. Record the appearance of the sample, including its lustre, in a table like the one shown in the Results section. Lustre is the shine given off from a material. A highly polished metal has high lustre (or is lustrous), while a piece of unvarnished wood might be dull (not lustrous).
2. Record whether you think the substance is malleable. A substance is malleable if it can be moulded into shape. If you were to hit the substance with a hammer, would it flatten or would it break?
3. Record whether you think the substance is ductile. A substance is ductile if it can be stretched into a wire. Do you think the substance could be pulled to make a thin wire?
4. Use sandpaper to scratch the surface of the material. If the fresh surface that you have uncovered is a different colour from the old surface, it is likely that the old surface had reacted with the air. This suggests that the material is **reactive**.
5. Check each of your samples for its **conductivity**:
   - Use the battery pack (or powerpack) to set up the electrical circuit as shown in Figure 3.7.2.
   - The lightbulb (which can be replaced by an ammeter or multimeter) will indicate whether a current is passing through the material and around the circuit.
   - Record the brightness of the lightbulb or the current measured with the ammeter/multimeter.

KEY TERMS

reactive readily undergoes chemical reactions
conductivity the ability of a material to conduct heat, sound or electrical energy



FIGURE 3.7.2 Using the equipment to test the conductivity of the iron nail

Results

Copy this table into your workbook and record your results in the table.

	Appearance	Malleable (yes/no?)	Ductile (yes/no?)	Reactive (yes/no?)	Conducts electricity (yes/no?)
iron nail					
stainless steel nail*					
copper strip					
magnesium strip					
chalk					
plastic					
brass tack*					
wood					
graphite					

*Note that brass and stainless steel are alloys.

Conclusion

Write a conclusion to your experiment by answering the following questions.

1. Metals are shiny, malleable, ductile and can conduct electricity. Non-metals are usually dull, brittle (break easily) and do not conduct electricity. Look at the substances you tested and classify them as metals or non-metals. (You can include the alloys as metals.)
2. Find the position of the pure metals used in this experiment on the periodic table. What do you notice about where they are?
3. Name the metals used to make brass and suggest why alloys like brass are normally shiny, malleable and ductile and can conduct electricity.
4. Iron is a fairly reactive metal (it forms rust when in contact with oxygen and water). Chromium is very resistant to corrosion. Suggest why stainless steel contains chromium.
5. Suggest why stainless steel is used instead of iron on boats.
6. Suggest why electrical wires are often coated with a plastic layer.

Evaluation

Evaluate your practical investigation by answering the following questions.

1. Were there any substances that were difficult to classify as metals? If so, why?
2. Identify any other challenges you encountered during this investigation.

3.8 Producing a metallic element

Introduction

What do you think would happen if you put a gold ring in a jar of water? What about a piece of iron?

Metals have varying degrees of reactivity. Consider the reactivity series of metals shown in Figure 3.8.1.

Looking at the list, you can see that potassium and sodium are very reactive, and that gold and platinum are less reactive. The reactivity of metals can be used to determine if one metal will replace another one from a solution.

In this practical investigation, you will use this idea to obtain copper metal from a solution of copper sulfate, using just a piece of zinc.

Background

The reactivity of metals can determine how a metal will react in certain scenarios.

In a displacement reaction, one element takes the place of another. For metals, this means that metal A will replace metal B in a solution if metal A is more reactive (higher in the series).

For example, aluminium is higher than lead on the reactivity series of metals. If a piece of aluminium is placed in a solution containing a lead compound, aluminium will take the place of lead in the compound dissolved in the solution. The lead that has been displaced ('pushed out') will form solid crystals of lead metal.

Aim

To form crystals of metallic copper

Prediction

Predict what will happen when zinc metal is added to a solution of copper sulfate.

Materials

- zinc (Zn) metal strip
- 0.1 M copper sulfate ($CuSO_4$) solution
- 100 mL beaker
- filter paper
- magnifying glass or microscope

Learning intention

To be able to conduct an experiment that involves the production of a metallic element from a compound

Success criteria

SC 1: I can conduct an experiment to investigate how an element is extracted from a solution of a compound.

SC 2: I can describe how copper as an element differs from the copper compound used in the experiment.

SC 3: I can suggest why zinc is used in the experiment.

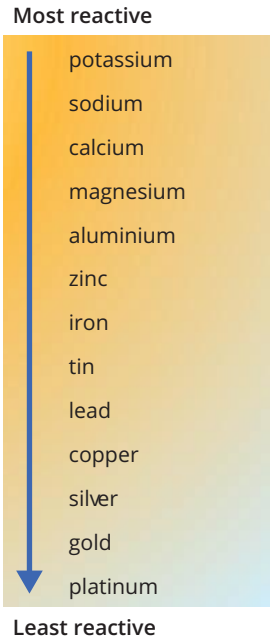


FIGURE 3.8.1 The reactivity series of metals

GO TO
Toolkit section 1.2, Making predictions from observations

SAFETY NOTES

- Copper sulfate is toxic, so wear gloves and safety glasses and avoid contact with eyes, skin and mouth.

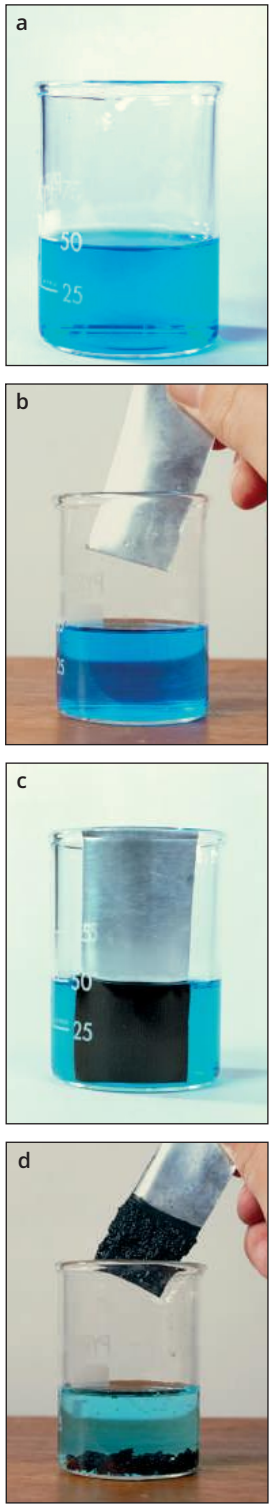


FIGURE 3.8.2 The experimental set-up

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. Add copper sulfate solution to the 50 mL mark on your beaker (step **a** in Figure 3.8.2).
2. Place the zinc metal strip so that it is partly immersed in the copper sulfate solution (steps **b** and **c** in Figure 3.8.2).
3. Observe the copper crystals as they deposit on the zinc strip.
4. Once you have seen a noticeable change, remove the zinc strip and place it on the filter paper (step **d** in Figure 3.8.2).

Results

Record your results using the following prompts.

1. Observations as the copper crystals form
2. Colour of the copper sulfate solution as the experiment proceeds
3. Detailed appearance of the copper crystals once you have removed the zinc strip (use a magnifying glass or microscope if possible)

Conclusion

Write a conclusion to your experiment by answering the following questions.

1. What elements, and how many atoms of each, are shown in the formula of copper sulfate?
2. Using evidence from your experiment, describe how copper as an element is different from the copper compound used in the experiment.
3. Explain why, over time, the solution became less blue.
4. Referring to the reactivity series of metals, explain why zinc is used in this experiment.
5. Based on its reactivity, suggest why copper is a good metal for making saucepans.

Evaluation

Evaluate your practical investigation by suggesting how the experiment could be altered or extended.

3.9 Particles in substances

Lesson overview

If you had a piece of aluminium tubing and a rubber tube, which one do you think would be easier to bend (Figure 3.9.1)? Why would this be so? The answer will be linked to the arrangement of atoms in the substance. The way that atoms are arranged and bonded together is called the structure of the substance.

In this lesson you will learn about the arrangement of atoms in different substances and how this contributes to the properties of the substances. You will also compare the key features of some types of structures.



Aluminium steel tube profile for the manufacture of windows and doors



Latex rubber tube for industry and sports

FIGURE 3.9.1 The arrangement of particles in rubber is different from the arrangement in aluminium; this makes rubber easier to bend than aluminium.

Learning intention

To understand that the particles in matter can have different arrangements

Success criteria

SC 1: I can recall the particle arrangement in elements, molecules, compounds, mixtures and pure substances.

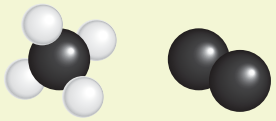
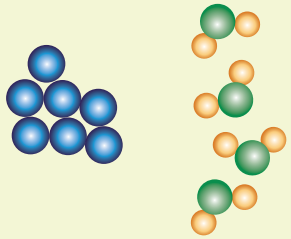
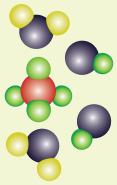
SC 2: I can compare the key features of structures including molecules, metals and non-metallic lattices.

SC 1 I can recall the particle arrangement in elements, molecules, compounds, mixtures and pure substances

Types of substances

Titanium, carbon dioxide and salt water can be all be classified differently according to the type of substance they are. Titanium is an element, carbon dioxide is a compound and salt water is a mixture. Particle diagrams (Table 3.9.1) show the relationships between these terms (and the terms atom, molecule and pure substance).

TABLE 3.9.1 Examples of particle diagrams

Atoms	Molecules	Pure substances	Mixtures
An atom.  A single atom on its own must be an element.	A molecule is two or more atoms combined.  It can be a compound (left) with more than one type of atom, or an element (right) with only one type of atom.	 A pure substance can be either an element (left) or a compound (right).	A mixture is made up of two or more substances that are not chemically combined.  Mixtures can be separated into pure substances.

SC 1 CHECK YOUR UNDERSTANDING

What is a pure substance, and how can it be identified in terms of particle arrangement?

SC 2 I can compare the key features of structures including molecules, metals and non-metallic lattices

The only elements that exist in nature as single atoms are the inert gases such as neon (Ne) and helium (He). Most elements do not exist as single atoms. Instead, the atoms are bonded together in a molecule or in a lattice structure.

Molecules

Many non-metallic elements exist as molecules (Figure 3.9.2). An example is oxygen (O). It exists as a molecule of two oxygen atoms joined together, which is written as (O_2). Every molecule of oxygen will have the same size and shape. Molecules such as these are sometimes called discrete molecules because each molecule is a separate particle.

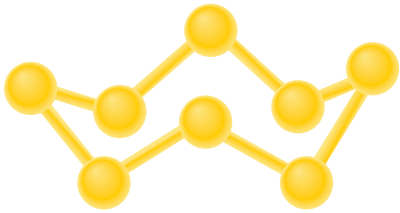


FIGURE 3.9.3 A sulfur molecule in the form of a ring

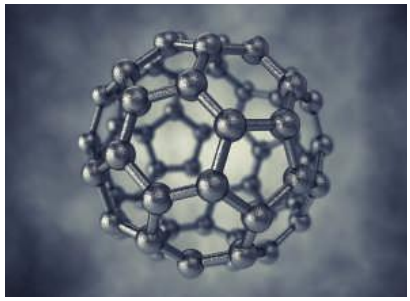


FIGURE 3.9.4 A buckyball is made up of 60 carbon atoms; it gets its name from looking like a soccer ball.

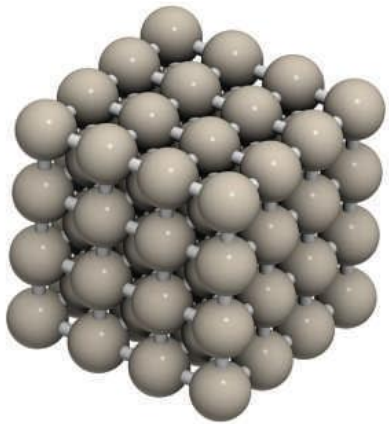


FIGURE 3.9.5 Iron atoms packed closely together



FIGURE 3.9.2 Most non-metallic elements exist as molecules.

Diatomic elements

Seven elements exist as diatomic molecules: hydrogen (H_2), nitrogen (N_2), oxygen (O_2), fluorine (F_2), chlorine (Cl_2), bromine (Br_2) and iodine (I_2). The prefix di- in diatomic means two. For example, nitrogen is represented by N_2, where the 2 indicates there are two nitrogen atoms in the molecule.

Some elements have more than two atoms in their molecules. For example, sulfur (S) molecules are made up of eight atoms in a ring and can be written as S_8 (Figure 3.9.3).

Carbon (C) can form giant molecules. One example is a molecule called buckminsterfullerene. It has 60 carbon atoms (C_{60}) joined together in a ball shape known as a buckyball (Figure 3.9.4).

Metals

Metals, such as iron, exist as closely packed atoms (Figure 3.9.5). They are held together by metallic bonds, which can act in all directions. Most elements in the periodic table are metals.

Metals are strong because of this arrangement. They are also malleable (able to be moulded into shape) and ductile (able to be drawn into wire) because when a force is applied to the metal, the atoms can 'slide over' each other into new positions without breaking the metallic bonds.

Non-metallic lattices

A **lattice** is a highly ordered arrangement of atoms in a repeating format. Non-metallic lattices tend to be very hard and strong. They cannot easily change shape, and are more likely to break, crack or shatter if a force is applied to them because the atoms cannot slide past each other.

KEY TERM

lattice a large network of atoms connected in a three-dimensional arrangement

Diamond

Diamond is one of the hardest materials known and diamonds are prized for their clarity (how clear they are) (Figure 3.9.6). Diamond is made of carbon in a lattice structure that results in its extreme hardness (Figure 3.9.7).



FIGURE 3.9.6 A crystal of pure diamond

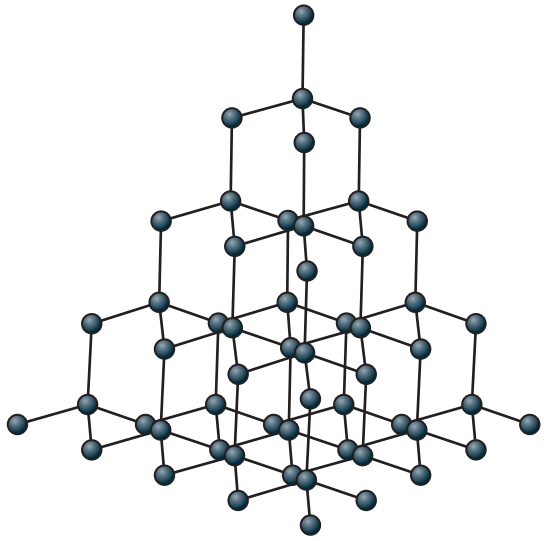


FIGURE 3.9.7 Carbon atoms held in a three-dimensional lattice in diamond

Graphite

Graphite is also a form of carbon but is black solid and much softer than diamond (Figure 3.9.8). This is because the arrangement of the carbon atoms is very different. The structure of graphite allows layers to be easily transferred to a piece of paper because the bonds between the layers are fairly weak (Figure 3.9.9).



FIGURE 3.9.8 Graphite, the form of carbon that can be used for pencils and drawing

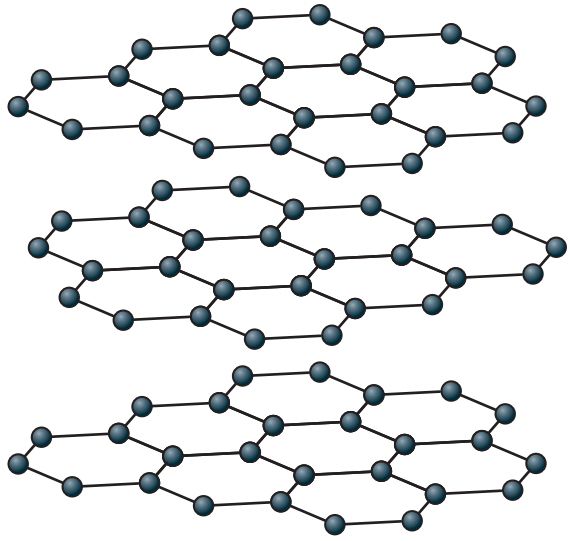


FIGURE 3.9.9 Carbon atoms in graphite with weak bonds between the layers

Silicon dioxide (silica)

Silicon dioxide (SiO_2) is the main compound in sand and is also known as silica (Figure 3.9.10). Its structure is a lattice with repeating atoms of silicon and oxygen joined together (Figure 3.9.11). Like diamond, there are no weak bonds in silicon dioxide.



FIGURE 3.9.10 Sand is a hard substance because its strong lattice structure.

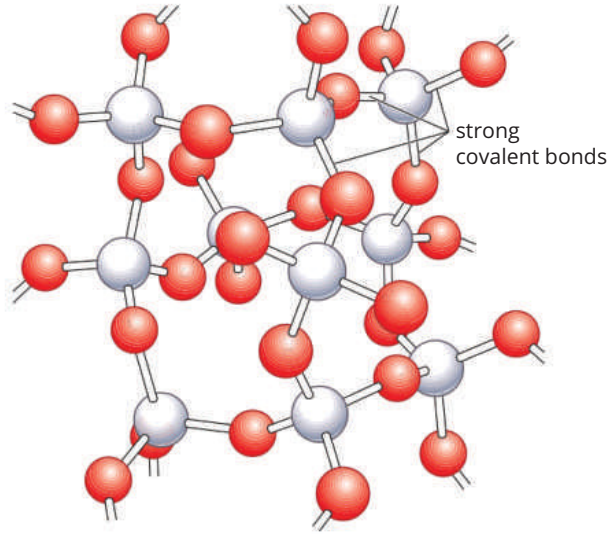


FIGURE 3.9.11 The structure of silica is similar to diamond, but with two types of atoms, silicon (white) and oxygen (red).

SC 2 CHECK YOUR UNDERSTANDING

Metals and some non-metals have lattice structures.

a Describe the key differences between the particle arrangements in metals and non-metallic lattices.

b Describe a key difference between the structures of graphite and diamond.

Lesson review

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

1 Compare the particle structures of oxygen (O_2) and diamond.

2 Describe how you would distinguish between a compound and a mixture by looking at a particle diagram.

3 In a metal, the bonds between atoms can act in all directions. Explain how this makes a metal difficult to break.

4 Use your understanding of how the atoms are arranged to explain why diamond is much harder than graphite, even though both are made of carbon atoms.

5 Copper (Cu) is an element that can be mixed with other metals to make alloys such as bronze (copper and tin) and brass (copper and zinc).

a Describe the particle arrangement in pure copper.

b Suggest how this arrangement would change if copper were part of a mixture, such as bronze.

3.10 Chemical formulas

Lesson overview

Would you drink dihydrogen monoxide? What if you knew that it is also called H_2O or water? Elements and compounds can be represented by their name or formula or with a diagram (Figure 3.10.1).

In compounds, the name often tells you what atoms are present, and how many there are of each.

In this lesson, you will learn about how to read chemical formulas and how to name certain molecular substances when you are given their formula.

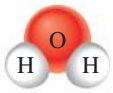
water H_2O 

FIGURE 3.10.1 There are a range of ways to represent compounds such as water

Learning intention

To understand how chemical formulas of compounds are written

Success criteria

SC 1: I can recall the formulas of some familiar chemical compounds.

SC 2: I can identify the types and numbers of atoms from chemical formulas of compounds.

SC 3: I can write the names of some unfamiliar molecular substances from their chemical formulas.

SC 1 I can recall the formulas of some familiar chemical compounds

Chemical formulas of common compounds

Many substances have a common name; for example, water, salt and ammonia, which have the formulas H_2O, NaCl and NH_3. Scientific (or systematic) names of compounds help show the elements they contain. For example, the name copper chloride shows that the compound contains the elements copper and chlorine.

Below are some examples of everyday compounds and their formulas (Table 3.10.1).

TABLE 3.10.1 Everyday compounds

Table salt	Carbon dioxide	Water	Sodium hydroxide (used in drain cleaners)	Ammonia (used in household cleaners)
				
Name: sodium chloride **Formula:** NaCl	**Name:** carbon dioxide **Formula:** CO_2	**Name:** water **Formula:** H_2O	**Name:** sodium hydroxide **Formula:** NaOH	**Name:** ammonia **Formula:** NH_3

SC 1 CHECK YOUR UNDERSTANDING

State the chemical formula of the following substances.

a sodium hydroxide **b** carbon dioxide **c** sodium chloride

SC 2 I can identify atoms from chemical formulas of compounds

Identifying atoms from chemical formulas of compounds

Every element has a unique symbol. A compound's chemical formula uses these symbols and says what elements it contains. It also uses numbers to show the relative number of atoms of each element there are in the compound.

SkillBuilder

Molecular formulas — what do they represent?

This SkillBuilder and the following Worked example will help you to:

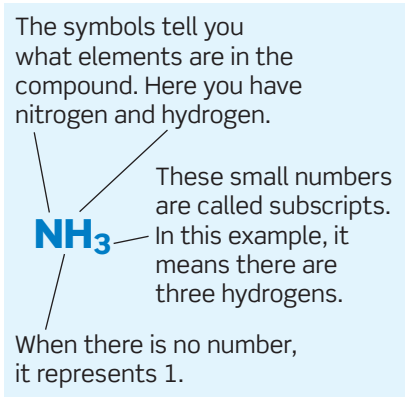
- identify elements from their symbols using a periodic table
- identify the numbers of atoms in a chemical formula.

How to determine the elements in a compound formula

1. Identify the symbols (remember that each one starts with a capital letter).
2. Determine the elements by using a periodic table.
3. Look at the small numbers (subscripts). These tell you how many of each atom there are. The subscript is always written on the right side of its element. If there is no number, then there is one atom.
4. If the chemical formula has the same element written more than once, add up all the atoms of each element. (Sometimes longer formulas are used to show how the atoms are joined together in complex molecules.)



Fertiliser like these white pellets often contains the compound ammonia, NH_3.



NH_3 shows that there is 1 nitrogen atom and 3 hydrogen atoms.

Examples

1. Ava was asked to determine the elements in the compound ammonia, which has a formula of NH_3.
   - There are two capital letters so there are two elements.
   - N means there is nitrogen. There is no number, so there is 1 nitrogen atom.
   - H means there is hydrogen. The subscript is 3, so there are 3 hydrogen atoms.
2. Lottie was asked to determine the elements in ethanoic acid (which is present in vinegar). Its formula is often written as CH_3COOH.
   - C means there is carbon. There are 2 letter C's, so there are 2 carbon atoms.
   - H means there is hydrogen. H appears as H_3 and H so in total there are 4 hydrogen atoms.
   - O means there is oxygen. There are 2 letter O's, so there are 2 oxygen atoms.
   - In total there are 2 carbon atoms, 4 hydrogen atoms and 2 oxygen atoms. Another way to write the formula is $C_2H_4O_2$.

Worked example

What do molecular formulas represent?

Problem

Phosphoric acid is the main acid in cola. Identify the types and numbers of atoms in a molecule of phosphoric acid. Its formula is H_3PO_4.



Cola contains the acid H_3PO_4.

Solution

Thinking	Working
Identify the elements in the compound by looking at the symbols.	There are three symbols: H (hydrogen), P (phosphorus) and O (oxygen).
Use the subscripts to identify the number of each atom.	Hydrogen has a subscript of 3 so there are 3 hydrogen atoms. Phosphorus does not have a subscript so there is 1 phosphorus atom. Oxygen has a subscript of 4 so there are 4 oxygen atoms in the molecule.
Summary	Hydrogen: 3 Phosphorus: 1 Oxygen: 4

Try yourself

Identify the types and numbers of atoms in copper chloride. Its formula is $CuCl_2$.

SC 2 CHECK YOUR UNDERSTANDING

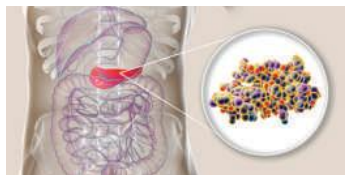
Glucose is a common type of sugar. It has the formula $C_6H_{12}O_6$. State the names of the elements present and the number of each type of atom.

Scifile

Insulin

Insulin is the compound that controls the level of glucose (a sugar) in blood. It is made in the pancreas, as shown in the diagram below. If there is not enough insulin, glucose builds up in the blood and cannot be used for energy release in the body's cells.

The formula of insulin is $C_{257}H_{383}N_{65}O_{77}S_6$! It is a type of protein and all proteins contain the elements carbon, oxygen, hydrogen and nitrogen.



Someone with diabetes either does not produce enough insulin or the insulin is not working correctly. In both cases, insulin may need to be injected to manage the person's sugar levels.

SC 3 I can write the names of some unfamiliar molecular substances from their chemical formulas.

Naming molecular compounds

When some pairs of elements combine, there may be more than one possible compound formed. In these situations, the names of the compounds indicate the number of atoms of the elements in the compounds. They do this by using prefixes, which are added at the front of a name of an element.

For example, when carbon and oxygen combine, there are two possible products:

- carbon dioxide with two oxygen atoms
- carbon monoxide with just one oxygen atom.

Air that is breathed out has carbon dioxide in it. Carbon monoxide is a poisonous gas that is often found around substances that burn. These two gases have names that sound quite similar except for a key difference; one is dioxide, and one is monoxide.

SkillBuilder

Writing a chemical name from a formula

This SkillBuilder will help you to:

- use the correct names to identify the elements present from a chemical formula
- use the correct prefixes at the start of the name to indicate the number of each type of atom in a chemical compound.

Writing the names of the elements

- The names of molecular compounds use the full name of the first element.
- The name of the second element is changed by using the stem of the element name, plus the suffix -ide at the end of the name.

Showing the number of atoms with prefixes

- The prefixes shown in Table 3.10.2 are used to indicate how many of each element are in a molecular compound.
  If there is only one atom of the first element, then a prefix is not used.

TABLE 3.10.2 Prefixes used to show the number of atoms in a molecular formula

Number of atoms	Prefix
1	mono-
2	di-
3	tri-
4	tetra-
5	penta-
6	hexa-

Examples

1 Declan was asked to name the substance with the formula CCl_4.

- There is one carbon atom, so its name stays as carbon and no prefix is needed.
- The name of the second element, chlorine, is changed to chloride, and tetra- is added before the name because there are 4 atoms of chlorine.

Therefore, the name is 'carbon tetrachloride'.

2 Isabella is asked to work out the systematic name for water H_2O.
She named the water 'dihydrogen monoxide' because there are two hydrogen atoms and only one oxygen atom. She has had to use the prefix mono- because the oxygen is the second element.

Non-systematic names

Many compounds that are used in everyday life, such as water (H_2O), are known by a common name. Other examples are CH_4 (methane) and NH_3 (ammonia). Their systematic names are carbon tetrahydride (for CH_4) and nitrogen trihydride (for NH_3).

SC 3 CHECK YOUR UNDERSTANDING

Give the scientific names of the following compounds.

a SO_3

b SiO_2

c PCl_5

d CF_4

Lesson review

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

1 The substance ammonia is used for household cleaning.
- **a** Give the formula of ammonia.
- **b** State the types and numbers of atoms present in a molecule of ammonia.
- **c** Ammonia can be reacted with nitric acid to form the substance ammonium nitrate (NH_4NO_3), which can be used as a fertiliser. State the types and numbers of atoms shown in the formula of ammonium nitrate.

2 The compound sodium dichromate is an orange solid with the formula $Na_2Cr_2O_7$. It was used in the past in breathalyser tests to indicate the amount of ethanol (an alcohol with a formula of C_2H_5OH) in the breath of a driver.
State the types and numbers of atoms shown in the formulas of these two compounds.

3 When nitrogen combines with oxygen, a range of compounds can be formed. These include NO, NO_2, N_2O and NO_5. Name these four compounds.

4 Consider the formula and name shown here.
Formula: P_2O_5
Name: phosphorus pentachloride
Rewrite the information so that is correct:
- **a** by changing the name to match the formula
- **b** by changing the formula to match the name.

3.11 Modelling the arrangement of atoms in compounds

Learning intention

To be able to compare information provided in symbols, formulas, two-dimensional models and three-dimensional models of substances

Success criteria

SC 1: I can construct scientific models to show the arrangement of particles in different substances.

SC 2: I can describe the information communicated by two-dimensional and three-dimensional models of substances.

SC 3: I can select an appropriate representation to communicate information to a specific audience.

Introduction

Atoms and molecules can be represented in different ways, including symbols, formulas, two-dimensional models and three-dimensional models. Models are a great way to visualise molecules. They enable you to see how the atoms join to make up the molecule, as in the model of glucose shown in Figure 3.11.1.

In this inquiry activity, you will use models to represent the arrangement of atoms in substances, and compare the information provided by different representations of compounds.

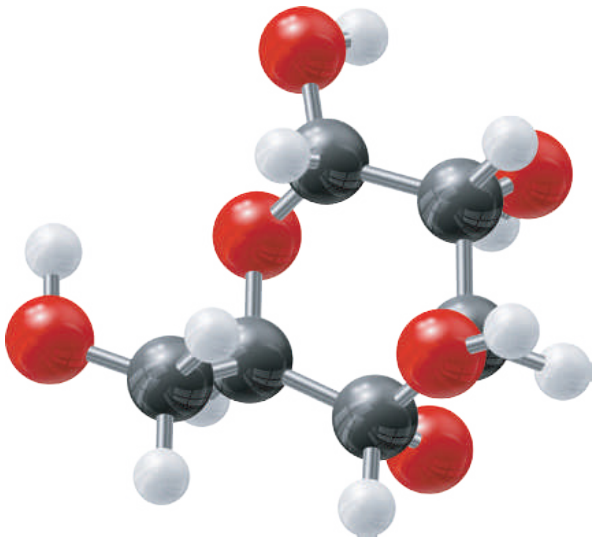


FIGURE 3.11.1 A model of a glucose molecule $C_6H_{12}O_6$, using 6 black balls to represent carbon, 12 white balls for hydrogen, and 6 red balls for oxygen

Background

In this activity, you will create models of a range of compounds. Some information is provided in the lesson, but you will also need to conduct research to discover how the atoms are arranged in the compounds.

Aim

To create models of compounds and compare information provided in symbols, formulas and models of substances

Plan

You are required to create two-dimensional and three-dimensional models of the following compounds:

- water molecule (H_2O)
- carbon dioxide molecule (CO_2)
- sulfuric acid molecule (H_2SO_4)
- glucose molecule ($C_6H_{12}O_6$)
- sodium chloride (NaCl) (see third hint)

Conduct research to collect any information that you need to complete this task.

HINT

There are different ways to model atoms, including plastic models, modelling clay or marshmallows with toothpicks.

When you make your models, try to take photos of them so they can be shared.

Design

Working with other students, decide on your approach to producing the two-dimensional and three-dimensional models of the compounds.

Make a list of any materials that you will need to complete the task.

HINT

In your research, you might see glucose molecules represented in two different ways, one with the carbon atoms in a ring and one with the carbon atoms in a line. Either can be used for this activity.

Conduct

1. Use paper, a whiteboard or a digital device to create two-dimensional representations of the compounds. Use colours and labels to show the key aspects of your model.
2. Ensure that your representations are saved so that they can be reviewed and shared later.
3. Use the materials provided to create three-dimensional models of each of the five compounds.
4. Compare your models to others in the class and encourage feedback from other students.

HINT

Note that sodium chloride is different from the other compounds because it is made up of a huge network (or lattice) of atoms and not individual molecules. Consider how you will represent a section of this lattice.

Improve

1. Describe how you could improve your two-dimensional representations.
2. Describe how you could improve your three-dimensional representations.

Evaluate

1. Describe how models can provide more information about a compound than the formula and compare the effectiveness of two-dimensional and three-dimensional models.
2. Scientists can use formulas, two-dimensional models or three-dimensional models to communicate information about a compound. Describe one situation where each of these would be the best to use, giving reasons for your answers.

GO TO

Toolkit sections 5.3, Using artificial intelligence (AI) in science writing and 5.1, Methods for presenting scientific ideas

3.12 Structure and properties of substances

Learning intention

To be able to relate the structure of substances to their observable properties

Success criteria

SC 1: I can record observations of the properties of a range of substances.

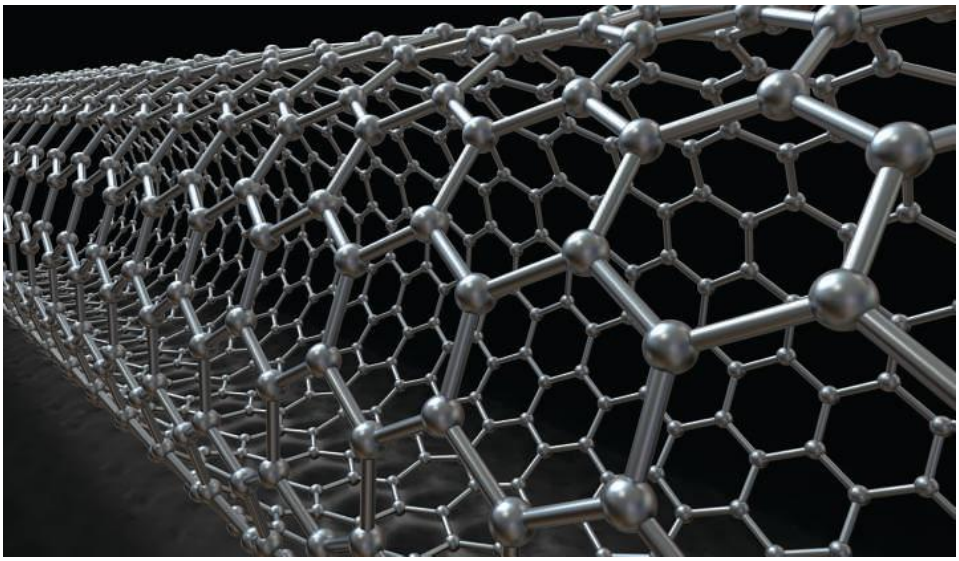
SC 2: I can use knowledge of structures to explain the differences between the hardness and melting points of substances.

SC 3: I can use observations of properties of a substance to predict the type of structure within the material.

Introduction

In this topic, different substances and their properties have been investigated. You have also learnt about how atoms are arranged into different structures and how those structures can be represented.

In this practical investigation, you will observe and test a range of substances and consider how each substance's structure, such as the arrangement of carbon atoms in a nanotube in Figure 3.12.1, contributes to its properties.



3.12.1 A model showing the arrangement of carbon atoms in a nanotube

Background

The arrangement of atoms in substances varies depending on the type of substance. For example, substances can contain molecules, they can be metals, or they can consist of a lattice.

In this practical investigation, you will observe the properties of some common substances and consider how their properties can be linked to their structure. The substances are:

Molecular substances	Metals	Substances consisting of lattices
water nitrogen (in air)	copper iron	salt (sodium chloride) sand

Aim

To investigate the properties of various substances and determine the relationship between their properties and their structure

Hypothesis

The properties of a substance are determined by the structure of the substance.

Prediction

Write a testable prediction for your investigation based on the hypothesis.

GO TO
Toolkit section 1.2, Making predictions from observations

Materials

- salt (sodium chloride)
- sand
- 2 cm lengths of copper wire
- small iron nails
- sandpaper or emery cloth (to clean the metals)
- 100 mL beakers
- Bunsen burner, tripod and gauze
- matches
- tin lid
- spatula
- tongs

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

- Turn off Bunsen burners or switch to a safety flame when not being used.
- Avoid direct contact with any hot objects.
- Wear safety glasses at all times.

Method

1. Construct a results table to record your observations. An example table is in the Results section.
2. Record the state and the appearance of the substances. For the metals, clean the surface using the sandpaper or emery cloth. For water, use tap water, and for nitrogen, use the air (which is 78% nitrogen).
3. Observe the hardness of the solids by touching (wash hands afterwards) or using a steel nail.
4. Test for solubility by placing a small amount of the substance in 50 mL of water and stirring.
5. Test the melting point of the solids by placing a small amount of the substance on a tin lid and heating for 30 seconds.

Results

Record your results in a table like this.

Structure	Substance	State	Appearance	Hardness	Solubility in water (soluble or insoluble)	Melting point (high or low)
molecular	water			N/A	N/A	
	nitrogen			N/A	N/A	
metal	copper					
	iron					
non-metallic lattices	salt					
	sand					

Conclusion

Write a conclusion to your experiment by answering the following questions.

1. For each of the three types of substances, list any similarities of the properties.
2. Using evidence from your experiment, describe how well your observations support the hypothesis.
3. Explain why substances that have lattice structures are hard and have high melting points.
4. Predict the type of structures present in diamond, in candle wax and in limestone, giving your reasons for each.

3 Classifying matter: Elements, compounds and mixtures

Topic summary

The key concepts included in this topic are:

- Elements are made up of only one type of atom.
- Compounds contain two or more elements combined together and the properties of compounds vary significantly from the properties of these elements.
- Air is a mixture of gases that have been used for a range of applications in society.
- Elements and compounds are pure substances with fixed compositions, whereas mixtures contain two or more pure substances that are not in fixed proportions and can be separated.
- Metallic elements have a range of distinctive properties including shiny appearance, malleability, strength, and the ability to conduct electricity.
- Particles in matter can have different arrangements and these affect the properties of the substance.
- The relative numbers of atoms in a compound can be shown using chemical formulas, and models can be used to show the arrangements of these atoms.

Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

Remember

1 State the symbols of the following elements. You can use a periodic table to help you answer this question.

a magnesium **b** manganese
c mendelevium **d** mercury

2 State the names of the elements represented by the following symbols. You can use a periodic table to help you answer this question.

a Au **b** Be **c** Ba **d** As

3 Identify which of the following substances are compounds: seawater, methane, mercury, glucose, germanium.

4 State four properties of metals.

5 Briefly describe how you can prepare hydrogen gas in the laboratory. Include the names of the chemicals required.

Understand

6 Identify which of the following substances do not contain molecules.

neon	sodium chloride	water
oxygen	gold	carbon monoxide

7 The symbol for copper is Cu and the symbol for iron is Fe.

a Describe where these symbols have been derived from.
b Explain why Co cannot be used for copper and Ir cannot be used for iron.

8 Using the examples of neon (Ne), nitrogen (N_2) and ammonia (NH_3):

a explain the difference between an atom and a molecule
b explain the difference between an element and a compound
c explain why the formula of nitrogen contains two atoms.

9 The element sodium (Na) is an extremely reactive metal and the element chlorine (Cl_2) is a toxic gas.

a State the common name, the scientific name and the formula of the compound produced when these elements combine.
b Describe the properties of the compound produced.
c Explain why the properties of the compound are so different from the properties of the two elements.

10 Diamond is the hardest known natural substance on earth and tungsten is one of the strongest metals.

- **a** Describe the difference between the terms 'strong' and 'hard'.
- **b** Draw a diagram in your notebook to explain why diamond is so hard.
- **c** Draw a diagram in your notebook to explain why tungsten is so strong.

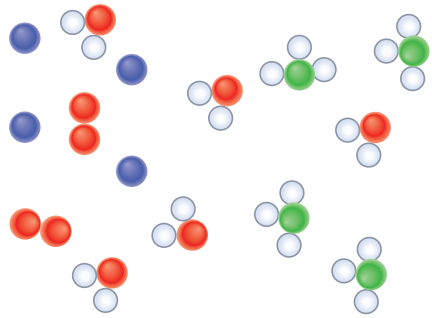
Apply

11 Ashbal was investigating the properties of elements and watched a video about the element potassium (K). He recorded the following observations from the video.

> 'The potassium was in a small cube that had a dull grey colour. It was cut in half with a knife and the inside was like silver. When a piece of the potassium was placed in cold water, there was lots of fizzing and smoke. Another piece of potassium was heated using a Bunsen burner and it caught fire straight away, with a lilac-coloured flame.'

Using these observations, list four properties of potassium.

12 Consider the particle diagram of a mixture below. Each colour represents a different element.



- **a** Describe the components of the mixture in terms of elements and compounds.
- **b** State whether you think this diagram represents a homogeneous or heterogeneous mixture.
- **c** Explain your answer to part b.

Analyse

14 Read the information about phlogiston and oxygen below.

> Before the discovery of oxygen, all substances that burned in air were thought to contain an element called phlogiston. After the substance had burned, it was believed that the phlogiston in the substance was 'used up'; however, instead of disappearing, it was released into the air. The released phlogiston then prevented other things burning in that air.
>
> Englishman Joseph Priestley is normally credited with the discovery of oxygen gas. He found that this gas made things burn more strongly and allowed some animals to live longer in it.
>
> When a candle burns in a limited supply of air, it will only burn for a short amount of time before going out.

- **a** Describe how this observation supports the theory of phlogiston as described above.
- **b** Describe this observation from your knowledge of the element oxygen.
- **c** It is now known that when candles burn, the compound carbon dioxide is given off. Use your knowledge of carbon dioxide to suggest why the candle in the description above stops burning.

13 Some students were investigating the properties of two substances. Their observations are summarised below.

Substance	State	Hardness	Solubility in water	Melting point	Effect when hit with hammer
A	solid	hard	insoluble	very high	changes shape
B	solid	very hard	soluble	very high	shatters

- **a** Identify which substance is a metal.
- **b** Use evidence from the observations to explain your answer.

15 Consider the following observations of the testing of some elements.

Element	Appearance	Effect of hitting with mallet
A	grey solid, some red solid on surface	fairly hard to bend
B	smooth yellow shiny solid	shatters
C	brown/orange shiny solid	flattened
D	white solid	no change in shape
E	black solid with smooth surface	cracks when hit
F	silver-like solid	bends a little

a Identify which of the above are likely to be metals.

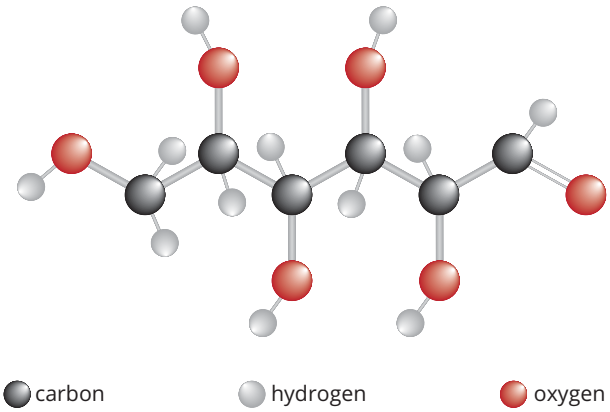
b Element C changes shape when it is hit. Name the property that allows the substance to do this.

c Describe a test that can be used to confirm which of the elements are metals.

d Suggest the identity of element C.

e Suggest the identity of element E.

16 Consider the model of a glucose molecule below.



a Use the model to write the chemical formula for glucose.

b Describe three things the model shows that cannot be worked out from just seeing the chemical formula.

c In the same style, draw a representation of a methane (CH_4) molecule.

Extension: Research task

17 The transition to renewable energy sources relies on the storage of electricity in batteries. This is because energy sources such as wind, solar and tidal power do not generate electricity at all times of the day or on every day of the year.

Australia is rich in a number of the elements required for the production of batteries, including silver, lead, lithium, cobalt, nickel and copper.

a Write the symbols of these six metals.

b Choose two of these metals and, by conducting your own research, describe how they are used in batteries. In your answer, you can include where the batteries are used and whether the metals are used in the batteries as elements or as compounds of the element.

c Choose two of the metals, which can be the same or different from those chosen for part b, and briefly describe how they are extracted from the earth. In your answer, you can include the name of the compounds in the earth and their formulas, where they are located in Australia and any risks associated with the extraction process.

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

acidic having the properties of an acid, or containing acid; having a pH of less than 7

allotrope a different form of the same element

alloy a homogeneous mixture of two or more metals

atom the smallest piece of individual matter that can exist by itself

cellular respiration a set of processes in cells that convert chemical energy from nutrients into energy used by cells

compound a pure substance that is made up of two or more different types of atom chemically joined

conductivity the ability of a material to conduct heat, sound or electrical energy

corrosion the breakdown of metals due to their reaction with other chemicals

distillation a process in which evaporation followed by condensation recovers solvents from mixtures

ductile able to be stretched to form a wire

element a substance made up of only one type of atom

fermentation the chemical process in which carbohydrate or sugar is broken down into a simpler substance, such as alcohol or an acid

formula a representation of a substance that uses chemical symbols and numbers to show the relative numbers of the atoms present in the substance

heterogeneous mixture a mixture that varies in composition and properties throughout

homogeneous mixture a mixture that has uniform composition and properties throughout

inert gas an element in group 18 of the periodic table that does not easily react because it has a full outer electron shell

lattice a large network of atoms connected in a three-dimensional arrangement

lustrous shines when polished or freshly cut

malleable able to be hammered or bent into new shapes

matter a physical substance; anything that has mass and volume

metal an element that is shiny, conducts heat and electricity, and can be hammered into sheets and drawn into wires

mixture a combination of two or more pure substances that can be separated to recover the pure substances

molecule a group of atoms joined together with chemical bonds

photosynthesis the chemical reaction in plants that converts carbon dioxide and water into oxygen and glucose using energy from the Sun

property an observable characteristics of a substance; what a substance looks like and how it behaves

soluble able to dissolve in a particular solvent

pure substance a material that is made up of only one type of substance

reactive a readily undergoes chemical reactions

TOPIC 4

Chemical change and energy

Substances can undergo physical or chemical changes. In a physical change, the appearance or state of a substance is altered, but its chemical composition remains the same. For example, a solid piece of gold can be melted into liquid gold, but it is still gold.

In contrast, a chemical change results in the formation of a new substance with different properties.

Chemistry is the modern form of the ancient science of alchemy, which included the search for the 'philosopher's stone'—a mythical substance believed to transform metals like mercury into gold.

Today, 118 chemical elements are known, and it is understood that chemistry cannot be used to create elements such as gold. However, elements can undergo chemical changes to form millions of different chemical compounds.

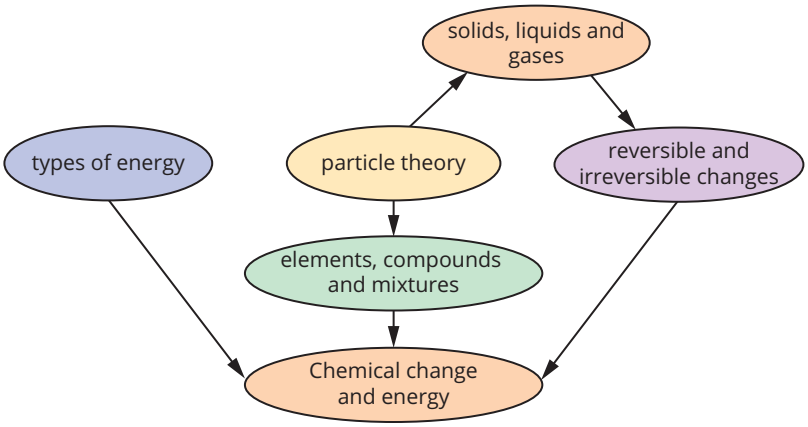
In this topic, you will learn about a range of chemical changes, how they vary from physical changes and how energy is involved.

Learning intentions

- ☐ To understand differences between physical and chemical changes **161**
- ☐ To be able to conduct a safe investigation that explores the differences between chemical and physical change **165**
- ☐ To be able to investigate how the promotion of the importance of biodegradable materials has informed individual and community viewpoints **167**
- ☐ To be able to describe examples of chemical reactions used by First Nations Australians **170**
- ☐ To be able to use physical change and chemical change to make and use a chemical indicator **173**
- ☐ To be able to plan, conduct and evaluate a reproducible investigation to identify whether a reaction is endothermic or exothermic **176**
- ☐ To understand that chemical reactions have inputs and outputs in terms of matter and energy **178**
- ☐ To understand how chemical reactions are represented by scientific models **185**
- ☐ To understand that combustion reactions produce heat and light **190**
- ☐ To understand that during a chemical reaction energy is released or absorbed **195**
- ☐ To be able to select and use appropriate equipment to investigate which chemical is the most effective for a cold pack that uses an endothermic reaction **202**
- ☐ To understand how world views relating to fairness in sport have led to the development of rapid chemical tests to identify performance-enhancing drugs **204**

4 Chemical change and energy

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.

Types of energy

1 List two everyday examples of energy.

Physical changes and changes in states

2 Describe the movement of and attraction between particles in solid iron, molten iron and iron vapour.

Reversible and irreversible changes

3 Identify whether the following processes are reversible or irreversible.

- **a** evaporation of seawater to form salt crystals
- **b** cooking pancake batter
- **c** cooking corn kernels to make popcorn
- **d** dissolving sugar in water

Particle theory

4 Draw a simple diagram of a solution using red circles to represent the solute and blue circles to represent the solvent.

Elements, compounds and mixtures

5 Categorise the following substances as elements, compounds or mixtures.

water, aluminium, steam, air, paper, hand sanitiser, helium, petrol

6 Mixtures can be separated into their parts. Which separation process will be best for the following?

- **a** removing coffee grounds from a pot of fresh coffee
- **b** obtaining pure water from salt water
- **c** determining the variety of colours in black ink
- **d** collecting salt from seawater

4.1 Physical and chemical change

Lesson overview

Changes to materials can be classified based on what happens to the substance involved.

If the substance stays as the same substance, but is changed in some other way, such as its shape or state, the change is called a physical change. An example of a physical change is ice melting (Figure 4.1.1).

If the substance changes into a different substance, this is a chemical change. An example of a chemical change is a bushfire (Figure 4.1.2), which changes the wood, leaves and other combustible materials into different products.

In this lesson, you will learn how to distinguish between physical and chemical changes and how to use the changes for a purpose.

Learning intention

To understand differences between physical and chemical changes

Success criteria

SC 1: I can list the observations that indicate that a chemical change has occurred.

SC 2: I can identify everyday examples of physical and chemical changes.

SC 3: I can predict the simple names of chemicals formed when elements combine to form compounds.



FIGURE 4.1.1 Ice melting to liquid water is an example of a physical change.



FIGURE 4.1.2 A bushfire is an example of a chemical change.

SC 1 I can list the observations that indicate that a chemical change has occurred

Evidence for chemical change

There are many types of evidence that show that a chemical reaction has taken place. These include colour changes (Figure 4.1.3), production of a gas, heat energy being released or absorbed or production of a solid (called a **precipitate**).



FIGURE 4.1.3 The colours of the tree leaves change from green to brown/orange due to chemical change in the leaves.

Chemical change

Substances that take part in chemical reactions are called **reactants**. The changes that can be observed during a **chemical change** are caused by the production of new substances, which are called **products** of the reaction. If the products have properties that are different from those of the reactants, it is usually easy to tell if a chemical change has occurred.

KEY TERMS

precipitate a solid formed during a chemical reaction
reactant a substance that takes part in a chemical reaction
chemical change a change that results in a new substance being formed
product a substance produced by a chemical reaction

KEY TERM

physical change a change that does not result in a new substance being produced



FIGURE 4.1.4 Cooking toast involves both a physical and a chemical change.

Physical and chemical changes

Sometimes chemical and **physical changes** can occur almost at the same time. For example, when you toast bread, the first thing that the heat from the toaster does is to dry the bread out (Figure 4.1.4). This is a physical change. Chemical change only happens when the bread starts to change colour. The heat of the toaster causes substances in the bread (e.g. sugars and proteins) to react together to form new substances.

A good way to tell the difference between physical and chemical changes is that most chemical changes cannot be reversed, but most physical changes can be reversed. You cannot 'uncook' toast! Therefore, cooking food normally involves a chemical change.

SC 1 CHECK YOUR UNDERSTANDING

Explain why a change in temperature might indicate a chemical change.

SC 2 I can identify everyday examples of physical and chemical changes

Table 4.1.1 and Table 4.1.2 present a range of everyday physical and chemical changes. Physical changes, such as melting, freezing, evaporation and condensation, do not create new substances. Instead, these physical processes just change the state or shape of the substance.

TABLE 4.1.1 Some examples of physical changes

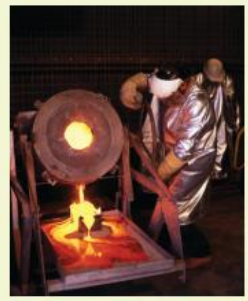
Boiling water	Making a gold bar
Although bubbles are seen, these are just water vapour, so no new substance is being produced. 	The gold is changing from liquid (molten) to solid. 

TABLE 4.1.2 Some examples of chemical changes

Silver tarnishing	Fireworks exploding
There is a colour change and a solid (silver sulfide) is being produced on the surface. 	There is a colour change, temperature change and new substances being produced. 

Scifile

Lighting a candle

Lighting a candle involves both physical and chemical changes. The wax melting is a physical change, whereas the wax burning to produce light and heat is a chemical change.



SC 2 CHECK YOUR UNDERSTANDING

You are cooking food on a barbecue. Classify the following processes as physical or chemical changes.



a cooking the meat patties

b lighting the gas using a spark

c accidentally melting the plastic spatula on the hotplate

d the solidification of the fats after the barbecue cools down

SC 3 I can predict the simple names of chemicals formed when elements combine to form compounds

Making chemical compounds

Chemical **elements** are substances that only contain one kind of atom. The simplest type of chemical change is when two elements combine to form a chemical **compound**. These are called **synthesis reactions**.

For example, when iron reacts with oxygen in the air, the product formed is rust, which has the chemical name iron oxide.

KEY TERMS

element a substance made up of only one type of atom
compound a pure substance that is made up of two or more different types of atoms chemically joined
synthesis reaction a chemical reaction in which one or more compounds are produced by the combination of elements

Word equations

Chemical changes are often called chemical reactions. The substances that are reacting together are called reactants and the substances produced are called the products.

Chemical reactions can be described using word equations, with the reactants on the left and the products on the right.

For example:

Iron + oxygen → iron oxide

This reaction shows how rust is formed (Figure 4.1.5).



FIGURE 4.1.5 Rust is formed by oxygen in the atmosphere reacting with iron.

Names of compounds

When two elements combine, the name of the compound formed can be predicted by combining the names of the elements. Often the name of the second element is changed by replacing the end of the name by -ide.

For example:

sodium + chlorine → sodium chloride

magnesium + oxygen → magnesium oxide

silver + sulfur → silver sulfide

HINTS

Prefixes used in names of molecular substances

Number of atoms	Prefix
1	mono-
2	di-
3	tri-
4	tetra-
5	penta-
6	hexa-

Names of chemicals that show numbers of atoms

When some pairs of elements combine, there may be more than one possible compound formed. In these situations, the names of the compounds indicate the number of atoms of the elements in the compounds. They do this by using prefixes, which are added at the front of a name of an element.

For example, when carbon and oxygen combine, there are two possible products:

- carbon dioxide with two oxygen atoms
- carbon monoxide with one oxygen atom.

Therefore, the word equation for the combination of oxygen and carbon could be:

carbon + oxygen → carbon dioxide

or:

carbon + oxygen → carbon monoxide

SC 3 CHECK YOUR UNDERSTANDING

Name the following products.

a carbon + four fluorine → ?

b nitrogen + two oxygen → ?

c phosphorus + five chlorine → ?

Lesson review

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

1 Name three observations that indicate a chemical change has occurred.

2 You are given two substances, substance A and substance B. When they are mixed, you observe a temperature increase and bubbling.

- **a** Does your observation suggest a physical or chemical change?
- **b** List the two observations that support your answer.
- **c** Explain why these observations indicate a chemical change.

3 Explain why boiling water is a physical change and not a chemical change.

4 Identify whether dissolving sugar in water is a physical or chemical change and justify your answer.

5 Nitrogen dioxide is a toxic gas that causes respiratory problems. The gas is a brown colour and is produced by industrial processes and emissions from motor vehicle exhausts. Determine the reactants required to form nitrogen dioxide.



6 You only need to be exposed to a tiny dose of hydrogen cyanide for it to be potentially fatal. Although hydrogen cyanide forms a colourless vapour, it has a bitter almond smell, like marzipan. A chemistry laboratory has a waste container where many different chemicals are emptied in after experiments. Predict the observations that would suggest that a chemical reaction has occurred, producing hydrogen cyanide.

4.2 Investigating evidence for chemical change

Introduction

There are many examples of physical changes happening around us. They can include changes of state, such as melting ice cream and boiling water. They can be substances mixing with each other, such as coffee dissolving in water. Physical changes can also be substances separating from each other, such as filtering tea leaves from a pot of tea. But there are many more changes occurring that are not just physical changes. These are the ones that create a different substance. These can include sugar changing into caramel or carbon dioxide being produced when bread is baked (Figure 4.2.1). These changes are called chemical changes.

In this practical investigation, you will observe some chemical changes and consider if the observable evidence suggests that a chemical change has occurred.

Background

A chemical change will produce substances that were not present before the reaction. Therefore, if you are looking for evidence of chemical change, look out for significant changes in properties as these new substances are being produced. Such changes could include colours changing, heat or light being produced, gases being produced that are not caused by liquids evaporating, and solids forming that are not caused by liquids freezing or by solutes crystallising.

Aim

To observe, record and compare observable evidence that chemical changes have occurred

Materials

- dilute hydrochloric acid (1.0 M)
- 2 cm strip of magnesium metal (ribbon)
- silver nitrate solution (0.1 M)
- sodium hydroxide solution (1.0 M)
- 4 large test tubes and a test-tube rack
- blue litmus paper
- 2 droppers
- thermometer

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 a safe investigation that explores the evidence for chemical and physical change

Success criteria

SC 1: I can conduct an investigation that identifies different signs of chemical change.

SC 2: I can use appropriate language and conventions when recording qualitative data.

SC 3: I can evaluate risks when examining chemical change and consider actions that can be taken to manage those risks.



FIGURE 4.2.1 Bread undergoes chemical changes while baking in an oven.

SAFETY NOTES

- Silver nitrate stains the skin.
- Hydrochloric acid and sodium hydroxide are corrosive and burn, so avoid skin contact and wear safety glasses.

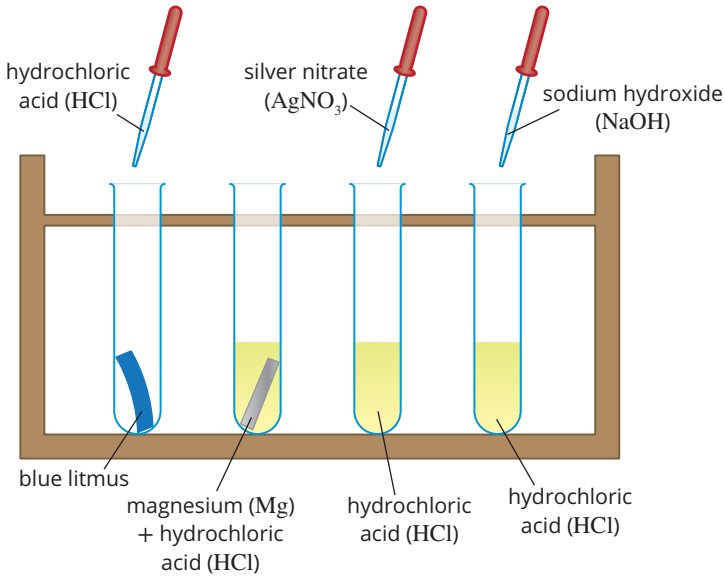


FIGURE 4.2.2 A simplified image of the experiment set-up

Method

1. Read the following steps and design a suitable results table to record your observations for the four test tubes.
2. Place the four test tubes in the test-tube rack. Figure 4.2.2 outlines the four tests you will be conducting.
3. Place a strip of blue litmus paper into test tube 1. Add 2 drops of dilute hydrochloric acid, using a clean dropper, and record your observations.
4. Add dilute hydrochloric acid to a depth of 2 cm in test tube 2. Add a small strip of magnesium ribbon and record your observations.
5. Add dilute hydrochloric acid to a depth of 2 cm in test tube 3. Add 10 drops of silver nitrate, using a clean dropper, and record your observations.
6. Add dilute hydrochloric acid to a depth of 2 cm in test tube 4. Use a thermometer to record the temperature of the hydrochloric acid, and then add 2 cm of sodium hydroxide solution. Record the temperature of the solution again.
7. Dispose of all the contents of the test tubes as directed by your teacher.

Results

Record your results in a suitable table.

Conclusion

For each test tube, describe the evidence you observed that showed that a chemical reaction had taken place.

Evaluation

GO TO
Toolkit section 2.1, Reducing risk

Evaluate your practical investigation by answering the following questions.

1. Describe two possible risks in this experiment and describe what action you took to reduce each of these risks.
2. Explain, by using your observations, the evidence of a chemical reaction in test tube 2.
3. Identify the test tube in which a solid was produced and explain how you knew that it was a solid.

4.3 Use of biodegradable materials

Introduction

Biodegradable materials are materials that can break down naturally in the environment without leaving behind harmful substances.

The promotion of their importance has helped shape the way people think about the materials they use and the impact they have on the environment. When people learn about the importance of biodegradable materials, it can influence their individual viewpoints. It can encourage them to choose products that are made from or packaged with biodegradable materials.

Community viewpoints can also be influenced by the promotion of biodegradable materials. When communities are educated about the benefits of biodegradable materials, it can lead to changes in local policies and practices.

In this inquiry activity, you will investigate how the promotion of the importance of biodegradable materials has informed individual and community viewpoints.

Background

Sustainability means using resources in a way that does not harm the environment, ensuring that future generations can also meet their needs. **Biodegradable** materials break down naturally in the environment without causing harm or leaving behind toxic residues. This means that they do not accumulate in the environment, reducing pollution and litter.

On the other hand, non-biodegradable materials, such as most plastics, can remain in the environment for hundreds of years, causing pollution and posing risks to wildlife and humans (Figure 4.3.1).



FIGURE 4.3.1 Non-biodegradable plastics take hundreds of years to breakdown in landfill.

Learning intention

To be able to investigate how the promotion of the importance of biodegradable materials has informed individual and community viewpoints

Success criteria

SC 1: I can describe how biodegradable materials can be used as an alternative to traditional plastics.

SC 2: I can explain how biodegradable materials promote sustainability.

SC 3: I can apply my understanding of biodegradable materials to a local community project.

KEY TERM

sustainability the conservation of resources in order to maintain a balance in a system, such as an ecosystem
biodegradable can break down naturally in the environment without causing harm or leaving behind toxic residues

Non-biodegradable plastics

KEY TERM

microbe a living organism, such as a bacterium or virus, that is too small to be seen by the naked eye; also called a microorganism

Most plastics are unreactive, meaning they do not react, or react only slowly, with other chemicals they come into contact with. This is beneficial for everyday use, as it prevents plastics from affecting the food they wrap, ensures their strength for packaging, and reduces the risk of harm if accidentally ingested. The chemicals in these plastics do not react with oxygen, water, acids or alkaline substances in the environment and are not broken down by **microbes**, as they provide no benefit to these organisms.

While these properties make plastics highly effective for their intended uses, they also make disposal challenging.

In addition, some plastics absorb dangerous chemicals, including heavy metals such as lead, pesticides and other toxic substances. When plastics are heated, they can release harmful chemicals into food and the air.

When plastic fragments become very small, they are called microplastics (Figure 4.3.2), which can enter the bodies of animals and plants worldwide. When these organisms are consumed, microplastics and the associated toxic substances can transfer through the food chain.



FIGURE 4.3.2 Microplastics separated from sand on a beach

For example, soil can contain microplastics from sources such as compost, weed mats, landfill waste and discarded plastics. Grass grown in this soil absorbs microplastics, which then accumulate in leaves and stems. When cows consume this grass, microplastics pass through their bodies and can be found in meat and milk. As a result, humans consuming dairy and meat products may also ingest and accumulate microplastics in their bodies.



FIGURE 4.3.3 Cups made from bamboo pulp are biodegradable products.

Biodegradable substances

A biodegradable substance is one that breaks down in the environment when microbes transform or alter the structure of chemicals that make up the substance. Natural materials, such as wood and leaves, and even humans, are naturally biodegradable. Because of advances in science and technology, plastics can now be made that share this property of biodegradability, but that are also strong enough and resilient enough to replace traditional non-biodegradable plastics (Figure 4.3.3).

Aim

To investigate how the promotion of the importance of biodegradable materials can change how people think about the use of biodegradable

Plan

1. Research how biodegradable materials can be used as an alternative to traditional plastics. Include specific details and try to include ethical, environmental, social or economic considerations where possible. Record your key findings.
2. Explore how the use of biodegradable materials improves sustainability. Record your key ideas.

Design

Consider how you might apply your understanding of biodegradable materials to a local community project. Design a project that you could start up, engage with or promote in your local community.

Conduct

How you conduct the project will depend on information provided by your teacher. Either as an individual, a group or a class, you may be able to use all your learning so far to plan and execute your local community project. Consider what your end goal is, a timeline, your audience, how you will measure success and what resources you need to support you.

Alternatively, you may be asked to present your project plan to a specific audience to receive feedback on your ideas. Record the key components of your plan, such as the people involved, the timeline, resources required, potential outcomes and how they can be measured and recorded.

Improve

Either from your experience of carrying out your plan, or from feedback received, describe how you could have improved your project.

Evaluate

Evaluate your investigation by considering the following questions.

1. Explain how the investigation of the use of biodegradable materials relates to chemical change.
2. Explain how the investigation of the use of biodegradable materials relates to sustainability.
3. Identify any new skills that you learnt by engaging in this inquiry activity.
4. Describe how your knowledge about biodegradable materials and sustainability increased throughout your community project.

4.4 First Nations Australians' use of chemistry

Learning intention

To be able to describe examples of chemical reactions used by First Nations Australians

Success criteria

SC 1: I can explain how a group of First Nations Australians uses a chemical reaction.

SC 2: I can compare the use of a chemical reaction to physical change used by First Nations Australians.

Introduction

First Nations Australians, often regarded as the world's earliest scientists, possess a profound understanding of the natural resources found on Country. This knowledge extends to the skilled extraction and use of various chemicals from their environment, such as resins and soap-like substances from plants and mineral pigments for artistic and cultural expression. Wood is not merely a structural element but a versatile resource for generating charcoal. It is also essential for heat production and controlled burning practices, which play a crucial role in land management.

In this inquiry activity, you will conduct some research into a chemical reaction harnessed by First Nations Australians and use this example to explore the differences between chemical and physical change.

Background

Chemical changes result in the creation of new substances with distinct chemical properties. Indicators of chemical changes include gas production, colour change, heat released or absorbed, and the formation of precipitates. In contrast, physical changes do not produce new substances; instead, they involve changes in the substance's appearance, shape, size, or state of matter. Physical changes are often reversible, and the original properties of the substance are retained. Recognising the difference between these two types of changes is essential for understanding the behaviour of matter in various processes.

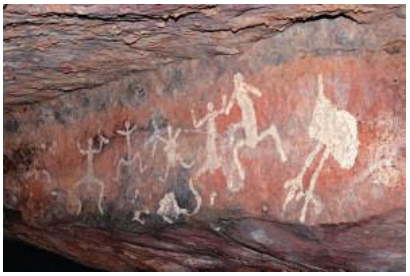


FIGURE 4.4.1 A range of chemicals produced by calcination are used in ancient rock art, such as this example at Gundabooka National Park, north-western New South Wales, outback Australia.

Chemical changes

Chemical reactions have been used by groups of First Nations Australians for thousands of years. Some important examples are outlined below.

Calcination

Calcination refers to the heating of a solid chemical so that it can decompose into different materials. When heated in this way, compounds such as water, carbon dioxide or sulfur dioxide are removed to leave behind a powdered product. One common example of this process as used by First Nations people is in the preparation of ochre, a natural earth pigment that typically consists of iron oxides and varying amounts of clay and sand. Calcination is used to enhance ochre colour and suitability for artistic applications (Figure 4.4.1).

Reduction

Reduction reactions are a different type of chemical reaction. An example is the reduction of iron ore using carbon in traditional smelting processes to produce iron metal and carbon dioxide. Reduction techniques, involving processes like controlled heating or grinding, have traditionally been used by First Nations communities to produce iron for tools like spear points or cutting implements.

Pyrolysis

Pyrolysis refers to a process similar to calcination in which the substance is heated intensely but without any air (or oxygen) present. This means that substances, such as wood, that would normally combust change instead into a purer form of carbon: charcoal (Figure 4.4.2).



FIGURE 4.4.2 Charcoal that has been produced from wood by pyrolysis

Extraction

Extraction is a process that removes a particular substance from a mixture, often using a solvent such as water. First Nations Australians extract pigments from the minerals and compounds in plants to use in art, ceremonies, and other forms of cultural expression.

Combustion

Combustion reactions involve oxygen combining with the substance (the fuel) that is burning. All combustion reactions release heat energy, which First Nations people use for light, warmth and cooking purposes, as well as in land management (Figure 4.4.3).



FIGURE 4.4.3 Combustion reactions have been used in Australia for land management for thousands of years.

Physical changes

First Nations Australians extract products from plant and animal materials by various separation techniques that involve physical processes like filtration and steam distillation, combined with chemical reactions like extraction and reduction, to obtain valuable resources such as:

- kakadu plum fruit, a rich source of vitamin C
- medicinal extracts, such as tea-tree and eucalyptus for essential oils with healing properties
- witchetty grubs, for skin healing and medicinal purposes (Figure 4.4.4)
- bush soap, which is derived from the red ash tree
- honey ants, used to extract sugar.



FIGURE 4.4.4 Witchetty grubs can be used as a source of food but the chemicals in them also have healing properties.

Filtration

Filtration is a separation process that involves passing a mixture through a filter, so that the residue remains behind and the filtrate passes through. First Nations Australians use sand or gravel beds to filter water, for example, allowing the sand to trap impurities and sediment while cleaner water passes through. In the preparation of plant extracts for medicinal or cultural practices, materials like cloth or natural fibres may be used to filter solid plant particles, separating the liquid from the solid components.

KEY TERM

nanotechnology using particles less than 100 nm (nanometres, or one-billionth of a metre) for technological improvements in science and engineering

Nanotechnology

Elements of **nanotechnology** can be seen in various traditional practices. Some groups of First Nations Australians employ fine, nanoscale particles in the hardening of wood for tools and other specialised purposes. Adding fine particles of charcoal, beeswax or fine sand and dust, for example, affects the physical properties of the resin from the grass tree (*Xanthorrhoea resinosa*) to form a glue without altering its chemical composition.

Aims

To discover how a group of First Nations Australians use a chemical reaction for a specific purpose

To compare this chemical change with a process of physical change also used by First Nations peoples

Plan

GO TO
Toolkit section 5.3, Using artificial intelligence (AI) in science writing

Conduct some preliminary research and select two processes in which First Nations peoples use substances for a specific purpose. Select one process that involves a chemical change, and one that only involves physical change. Make a note of your chosen processes.

Design

Consider how you will learn more about these two processes: where they are used and by whom, what they are used for, and the key differences between them. Make notes or create a mind map to outline your approach, including the name of resources you might use for your research.

Conduct

GO TO
Toolkit sections 5.1, Methods for presenting scientific ideas and 5.2, Using scientific language

1. Write a brief description of the chemical process you are investigating. Include the names of the reactants and the products of the chemical reaction.
2. Give the name and/or location of the First Nations peoples that use or have used the process. Explain how the reactants are sourced, how the chemical reaction is carried out and the uses of the product(s) formed.
3. Compare this example of a chemical change with a process also used by First Nations peoples that involves one or more physical changes.

Evaluate

Evaluate the use of chemical changes for practical applications by First Nations Australians. Consider the chemical reactions used in processes such as calcination, reduction, pyrolysis, extraction and combustion in your response.

Design a way to compare the process that uses a chemical change and the process that uses only physical changes. You can use a table or other form of graphic organiser. Use your knowledge of chemical and physical changes, including the observable evidence for chemical change, to design your answer.

4.5 Making and using a chemical indicator

Introduction

Acids are substances that have distinctive properties, such as being corrosive and having a sour taste. **Alkalis** are the chemical opposite of acids. They can have a bitter taste and often feel soapy to touch. Substances, such as pure water, that are neither acid nor alkaline, are described as being **neutral**.

Chemical indicators are substances that will change colour depending on whether they are in acidic, alkaline or neutral conditions (Figure 4.5.1).

In this practical investigation, you will use separation techniques to extract chemicals from red cabbage that can act as a chemical indicator, and then use the indicator to test a range of substances.

Background

Many plant-based substances contain chemicals that change colour depending on the level of acidity or alkalinity in their environment. For example, the colour of the flowers of geraniums, butterfly peas, hydrangeas (Figure 4.5.2), roses and tulips depend on the acidity of the soil that they are growing in.



FIGURE 4.5.2 The hydrangea on the left has been grown in an acidic soil, the centre one in neutral soil and the one on the right in alkali soil.

If the chemicals that cause these changes can be extracted, they can be used to test the acidity of a range of other substances and mixtures. Red cabbage contains chemicals that can act as chemical indicators, which are soluble in water. This means the chemical indicator can be separated from the other parts of the cabbage leaves.

Scifile

Red cabbage indicator

The substance in red cabbage that changes colour is called anthocyanin. Anthocyanin carries out reversible reactions with the acidity or alkalinity of the solution that is being tested. The colour change is due the chemical structure of anthocyanin changing its shape.

Learning intention

To be able to use physical change and chemical change to make and use a chemical indicator

Success criteria

SC 1: I can take action to minimise risk when conducting an experiment.

SC 2: I can explain how the separation of pigment from a cabbage involves physical changes.

SC 3: I can explain, with evidence, why the use of the indicator to test substances involves chemical changes.



FIGURE 4.5.1 The citric acid in lemon juice can turn a chemical indicator a red colour.

KEY TERMS

acid a chemical that, when dissolved in water, is corrosive, can react with reactive metals to form hydrogen gas and has a pH of less than 7; foods that are acidic have a sour taste

alkali a chemical that, when dissolved in water, can react with organic tissue and has a pH of more than 7; foods that are alkaline have a bitter taste

neutral neither acidic nor alkaline

Aim

To safely make a chemical indicator from red cabbage and to evaluate how effective the indicator is at testing the acidity of a range of solutions and mixtures

Materials

- a few millilitres each of dilute hydrochloric acid (0.1 M), dilute sodium hydroxide solution (0.1 M), vinegar, salt (sodium chloride) solution, distilled water, soft drink and lemon juice
- 1 antacid tablet (such as Alka Seltzer), broken into small pieces
- red cabbage leaves (or red flower petals, such as carnation, rose or geranium)
- filter funnel, filter paper and conical flask
- 250 mL beaker
- eyedropper
- hotplate or Bunsen burner, tripod, gauze mat and bench mat
- 9 test tubes and test-tube rack
- matches

SAFETY NOTE

- Most chemicals in this experiment are corrosive or caustic, so wear rubber gloves, protective clothing and safety glasses at all times.

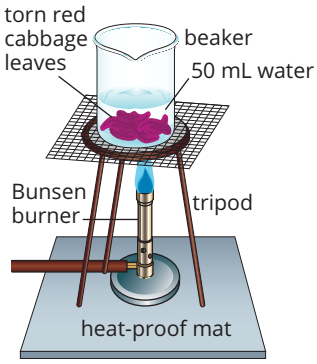


FIGURE 4.5.3 The set-up to extract the chemical indicator from red cabbage leaves

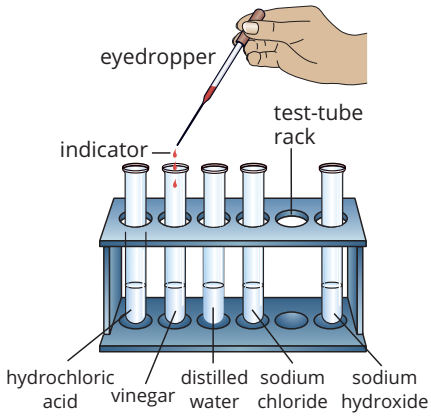


FIGURE 4.5.4 A simplified image of your experimental set-up for testing the indicator with acidic and alkaline substances

Assessment of risk

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

Method

Part A: Making the indicator

1. Tear up one or two red cabbage leaves and place them in the beaker with enough water so that the cabbage is just covered (Figure 4.5.3).
2. Heat the beaker until the water is gently boiling. Continue to boil the water until it has been strongly coloured red by the cabbage leaves.
3. Allow the water to cool and then filter it to remove the cabbage leaves, collecting the indicator solution in the conical flask.

Part B: Testing the indicator

4. Copy the table in the Results section in your notebook.
5. Figure 4.5.4 demonstrates how to set up your experiment. Using an eyedropper, add about:
   - 1 cm of dilute hydrochloric acid to test tube 1
   - 1 cm of vinegar to test tube 2
   - 1 cm of distilled water to test tube 3
   - 1 cm of salt (sodium chloride) solution to test tube 4
   - 1 cm of sodium hydroxide solution to test tube 5.
6. Add a few drops of your indicator to each test tube and record the colour in the results table.

Part C: Testing unknowns

7 Add about 1 cm of lemon juice to test tube 6.

8 Add about 1 cm of soft drink to test tube 7.

9 Add about 1 cm of tap water to test tube 8.

10 Add the pieces of antacid tablet to test tube 9.

11 Add a few drops of your indicator to each test tube and record the colour in the results table.

Results

Record your results in a table.

Test tube	Name of substance	Colour with red cabbage indicator	Type of substance
1	hydrochloric acid solution		strong acid
2	vinegar		weak acid
3	distilled water		neutral
4	salt solution		neutral
5	sodium hydroxide solution		strong alkali
6	lemon juice		
7	soft drink		
8	tap water		
9	antacid		

Conclusion

Use the colours from the known solutions to classify the four unknown substances and add this to your results table.

Evaluation

Evaluate your practical investigation by answering the following questions.

1 Explain the actions that you took to minimise risk in this experiment.

2 Describe the physical changes that took place in the extraction of the indicator from the red cabbage.

3 Compare, using evidence from your observations, the chemical changes that took place in Parts B and C of the experiment to the changes in Part A of the experiment.

GO TO
Toolkit section 2.1, Reducing risk

4.6 Identifying energy change in a chemical reaction

Learning intention

To be able to plan, conduct and evaluate a reproducible investigation to identify whether a reaction is endothermic or exothermic

Success criteria

SC 1: I can design a valid experiment that tests whether a reaction is endothermic or exothermic.

SC 2: I can identify and manage risks in conducting an experiment involving exothermic and endothermic reactions.

SC 3: I can evaluate the validity of experimental data.

KEY TERMS

chemical reaction the process of rearranging atoms in substances to form different substances

exothermic reaction a chemical reaction that releases energy, often causing a temperature increase in the surroundings

endothermic reaction a chemical reaction that absorbs energy, often causing a temperature decrease in the surroundings

Introduction

One of the pieces of evidence that a chemical change (chemical reaction) has taken place is an increase or a decrease in temperature. This is because chemical reactions involve energy.

Reactions that cause the temperature to increase are called exothermic reactions. An example of an exothermic reaction is a burning match (Figure 4.6.1). Reactions that cause the temperature to decrease are called endothermic reactions.

In this practical investigation you will plan and carry out an experiment to test whether a chemical reaction is exothermic or endothermic.

Background

When new substances (products) are made in **chemical reactions**, the new chemicals may contain different amounts of chemical energy.

Reactions that cause the temperature to increase are called **exothermic reactions**. The products have less chemical energy than the reactants and heat energy is released into the environment, causing an increase in temperature. Sugar contains a large amount of stored chemical energy and so typically takes part exothermic reactions with other substances (Figure 4.6.2).



FIGURE 4.6.1 A burning match is an example of an exothermic reaction.



FIGURE 4.6.2 Sugar is a chemical that contains a large amount of stored chemical energy.

Reactions that cause the temperature to decrease are called **endothermic reactions**. The products have more chemical energy than the reactants and heat energy is removed from the environment, causing a decrease in temperature.

In this practical investigation, you will carry out a chemical reaction and test whether it is exothermic or endothermic.

Aim

To determine whether a reaction between an acid and an alkali is endothermic or exothermic

Hypothesis

State, with reasoning, whether you think the reaction of an acid and an alkali is exothermic or endothermic.

Materials

You will have access to solid citric acid as your acid and baking soda (sodium hydrogen carbonate) as your alkali. Your teacher will tell you how much you are able to use for the experiment. Include the list of required materials and safety notes as part of your method.

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

Write a step-by-step method for your investigation. Include quantities required and any safety notes required.

Prediction

Write a prediction for your investigation.

Results

Record your results in a suitable table.

Conclusion

Comment on whether your results support your hypothesis.

Evaluation

Evaluate your practical investigation by answering the following questions:

1. Describe how you ensured that your experiment was valid.
2. Comment on whether you think you need to conduct any further experiments to test your hypothesis.

HINT

Terminology tip

Look carefully at the terms 'exothermic' and 'endothermic'. They both end in the suffix -thermic, which means relating to heat or temperature.

Exothermic has the prefix exo-, which means exterior (or outside). This means that exothermic is linked to sending heat 'out of' the chemicals.

Endothermic has the prefix endo-, which means internal (or inside). This means that endothermic is linked to heat being absorbed from the environment.

SAFETY NOTE

- Citric acid is a mild irritant, so wear safety glasses and avoid contact with your skin.

GO TO
Toolkit section 2.1, Reducing risk

HINTS

You can conduct preliminary trials to test and improve your method.

Water is required for the reaction between the acid and the alkali to occur.

The reliability of your results can be improved by carrying out repeat trials.

GO TO
Toolkit section 4.2, Evaluating validity

4.7 Reactants, products and energy in a chemical reaction

Learning intention

To understand that chemical reactions have inputs and outputs in terms of matter and energy

Success criteria

SC 1: I can identify the products and reactants of chemical reactions.

SC 2: I can describe energy inputs and outputs in chemical reactions.

SC 3: I can describe common uses of products or energy outputs from chemical reactions.



FIGURE 4.7.1 Magnesium ribbon burns in oxygen to produce solid magnesium oxide.

Lesson overview

There are many different types of chemical reactions, but they all have some things in common. They always result in substances (chemicals) changing into different chemicals. Cellular respiration, digestion of food in your stomach, and the movement of nerve impulses through your body involve chemical reactions.

In this lesson, you will learn about chemical reactions, how they can be represented and how they can be considered as processes that have inputs and outputs.

SC 1 I can identify the products and reactants of chemical reactions

All chemical reactions can be represented by equations.

A chemical equation tells the story of a chemical reaction, with the reactants (the 'start of the story') on the left-hand side and the products (the 'end of the story') on the right-hand side.

The plus signs (+) mean 'reacts with' and an arrow (→) means 'changes into'.

For example: hydrogen reacts with oxygen, which changes into water:

hydrogen + oxygen → water (this is called a word equation)

Reactions can also be represented with equations that use the chemical formulas of the substances involved.

$2H_2 + O_2 \rightarrow 2H_2O$

Many types of chemical reactions occur in everyday life, including combustion, corrosion, respiration, photosynthesis and the reaction of acid with reactive metals.

Combustion

Combustion is the burning of a substance in the presence of oxygen.
The products of combustion are chemicals called oxides, which are produced when the oxygen combines with the reactant.

Examples:

magnesium (Mg) + oxygen (O_2) → magnesium oxide (MgO) (Figure 4.7.1)

carbon (C) + oxygen (O_2) → carbon dioxide (CO_2)

Corrosion

Corrosion occurs when metals react with oxygen. Corrosion is like combustion because oxides are also formed. However, corrosion is a much slower chemical process.

Example:

iron (Fe) + oxygen (O_2) → iron oxide (Fe_2O_3) (rust)

Corrosion happens more quickly in the presence of water. This is why objects made of iron, or iron alloys such as steel, rust if the metal stays wet (Figure 4.7.2). The rate of corrosion is also increased if other chemicals such as salt and acids are present.



FIGURE 4.7.2 A rusty shipwreck—the brown substance is iron oxide.

Cellular respiration

Cellular respiration is a chemical reaction that also needs oxygen. It occurs in the mitochondria of plant and animal cells (Figure 4.7.3). It requires glucose ($C_6H_{12}O_6$) as a reactant and is how the cells generate energy. Cellular respiration is a process that involves several individual chemical reactions. It can be summarised by the following word equation.

oxygen + glucose → carbon dioxide + water

The oxygen comes from the surrounding air. The glucose comes from the breakdown of carbohydrates and sugars.

The carbon dioxide is released back into the atmosphere; for example, through the lungs of animals, the gills of fish or the leaves of plants.

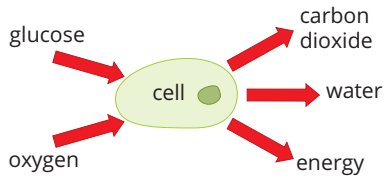


FIGURE 4.7.3 Cellular respiration is a chemical reaction that converts glucose and oxygen into carbon dioxide and water, and releases energy.

Photosynthesis

Photosynthesis is a chemical reaction that occurs in the leaves of plants using energy from sunlight. It can be summarised as:

carbon dioxide + water → oxygen + glucose

The carbon dioxide comes from the surrounding air and the water normally comes from the soil through the roots of the plant. The glucose is then used by plants for energy. The oxygen is released back into the atmosphere (Figure 4.7.4).

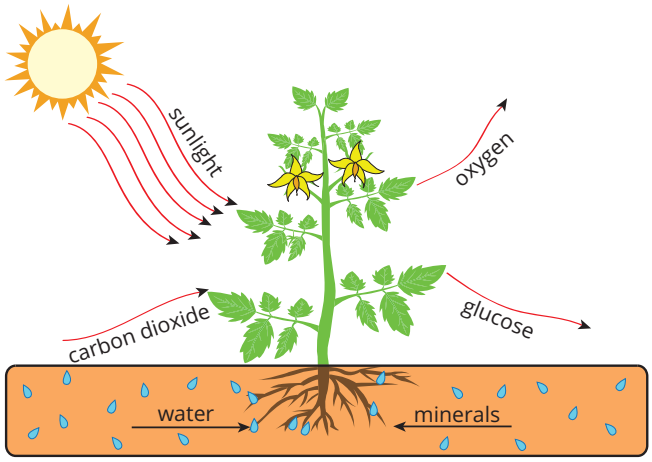


FIGURE 4.7.4 The inputs and outputs of photosynthesis

Scifile

Anaerobic respiration

There are microorganisms that undergo respiration without oxygen gas. They live in conditions where oxygen gas is not present, such as the bottom of lakes and oceans and in animal digestive tracts. These microorganisms use other substances in their surrounding environment to react with glucose to give them energy. One example is denitrifying bacteria, which use a substance called nitrate instead of oxygen.



FIGURE 4.7.5 Magnesium reacts with acid to produce hydrogen gas; magnesium powder reacts faster than magnesium ribbon.

Acids and reactive metals

Reactive metals, such as magnesium (Mg) and sodium (Na), react with acids to produce hydrogen (H_2). The other product is called a salt, and the name of the salt produced depends on which metal and which acid are reacting with each other (Figure 4.7.5).

Examples:

sodium (Na) + hydrochloric acid (HCl) → hydrogen (H_2) + sodium chloride (NaCl) (commonly known as table salt)

magnesium (Mg) + sulfuric acid (H_2SO_4) → hydrogen (H_2) + magnesium sulfate ($MgSO_4$) (commonly known as Epsom salts)

SC 1 CHECK YOUR UNDERSTANDING

List the reactants and products in the combustion of magnesium.

SC 2 I can describe energy inputs and outputs in chemical reactions

Chemical reactions

A chemical reaction can be considered as a system that is made up of key components.

- Reactants—the chemicals that are used in the reaction.
- Products—the chemicals that are produced in the reaction.
- Surroundings—the environment in which the reaction takes place; this could be the surrounding air or the water if the reaction involves solutions of chemicals.

Reactants and products

The chemicals involved in chemical reactions contain stored chemical energy. You cannot see or feel this energy. However, any change to the amount of stored chemical energy has the potential to make a difference to the energy of the surroundings. Therefore, stored chemical energy is often called chemical potential energy.

For example, the stored chemical energy in a bar of chocolate can be transformed to energy that your body needs.



FIGURE 4.7.6 Light energy can be released into the surrounding environment, such as the coloured light from fireworks.

The surroundings

Energy from chemical reactions can be released into the surroundings in a range of forms: heat (e.g. a gas stove), light (e.g. the fireworks shown in Figure 4.7.6), kinetic (e.g. the release of gas in an airbag) or electrical energy (e.g. batteries).

Chemical reactions can also absorb different types of energy from the surroundings. Heat energy can be absorbed from the surroundings, causing the surroundings to cool down. An example of this is an instant cold pack used to treat sports injuries (Figure 4.7.7). Light energy can be absorbed from the surroundings, as in the photosynthesis reaction that uses ultraviolet and visible light to produce glucose in plants. Electrical energy, or electricity, can be used in reactions to produce chemicals. An example is electricity used to produce aluminium from aluminium oxide (alumina) in a process called electrolysis.



FIGURE 4.7.7 An instant cold pack absorbs heat from the surroundings.

Exothermic and endothermic reactions

Reactions can be classified according to their effect of the environment.

- Exothermic reactions release heat energy into the surroundings, causing an increase in temperature.
- Endothermic reactions absorb heat energy from the surroundings, causing a decrease in temperature.

Heat as an input or an output

For exothermic reactions, heat energy is an output. It can be added to the right-hand side of the equation.

For example, the reaction that occurs in petrol-fuelled car engines is the combustion of octane:

octane (C_8H_{18}) + oxygen (O_2) → carbon dioxide (CO_2) + water (H_2O) + HEAT

For endothermic reactions, heat energy is an input. It can be added to the left-hand side of the equation.

For example, the reaction that occurs when limestone (calcium carbonate) is converted to quick lime (calcium oxide):

HEAT + calcium carbonate ($CaCO_3$) → calcium oxide (CaO) + carbon dioxide (CO_2)



FIGURE 4.7.8 Lighting a Bunsen burner with a match is an example of an exothermic reaction.

Heat used to start a reaction

Sometimes heat is required to get a reaction to start; for example, using a burning match to light a Bunsen burner (Figure 4.7.8). However, once the reaction is going, it will continue to release heat. Therefore, despite the small amount of energy needed to start this reaction, much more is released, making it overall exothermic.

SC 2 CHECK YOUR UNDERSTANDING

Describe one form of energy that is released in an exothermic reaction and explain why that energy is released.

SC 3 I can describe common uses of products or energy outputs from chemical reactions

Chemical reactions can be used to produce useful products or generate energy, often in the form of heat. The raw materials used for the reactions often have to be purified by physical separation methods before they take part in the chemical reaction.

Useful products

The following processes use chemistry to create useful products. In some cases, the overall processes might involve many reactions and the equation shown is a summary of the processes involved.

Iron from iron ore



FIGURE 4.7.9 Molten iron produced from iron oxide in a blast furnace

Iron ore contains mainly iron oxide (Fe_2O_3). The iron ore is crushed and separated from waste materials such as rock. It then takes part in a reaction with carbon monoxide (CO). The oxygen (O_2) is removed from the iron oxide (Fe_2O_3) to produce molten iron (Fe). Heat is used to help the reaction start, but overall this is an exothermic reaction (Figure 4.7.9). The iron (Fe) produced can be used in the construction industry.

iron oxide + carbon monoxide → iron + carbon dioxide + HEAT

Making plastics



FIGURE 4.7.10 Part of an industrial plant used to manufacture polyethene

Plastics are made up of large molecules called polymers that can be made of thousands of atoms. An example of a plastic polymer is polyethene. Polyethene is made by reacting ethene (C_2H_4) molecules with each other. The ethene molecules join together to form larger molecules called polyethene.

The ethene reactant is placed under high pressure to help the molecules react together (Figure 4.7.10). Other chemicals, called catalysts, are also added to make the reaction happen faster, but these are not used up in the reaction.

many ethene molecules → polyethene

Making fertilisers



FIGURE 4.7.11 Ammonium nitrate fertiliser

Most fertilisers used in agriculture contain one or more of the elements nitrogen (N), phosphorus (P) or potassium (K). Fertilisers are used to provide more efficient plant growth (Figure 4.7.11).

Ammonium nitrate (NH_4NO_3) is a very commonly used fertiliser that can be produced by reacting concentrated nitric acid (HNO_3) with ammonia gas (NH_3). The reaction is highly exothermic.

nitric acid + ammonia → ammonium nitrate + HEAT

Making soap



FIGURE 4.7.12 Soap is made by the reaction of sodium hydroxide and a fat or an oil.

If you add a strong alkali, such as sodium hydroxide, to an animal- or a plant-based oil, the alkali can convert the oil to soap (Figure 4.7.12). Fats and oils, such as beef fat, coconut oil and olive oil, contain different combinations of chemicals called fatty acids. Therefore, different oils will produce soaps with different properties. Coconut oil contains a high percentage of lauric acid, so the soap produced from coconut oil will be called sodium laurate. Glycerol (sometimes called glycerine) is produced as a by-product.

The formation of soaps can be represented as:

sodium hydroxide + natural fat/oil → soap + glycerol

Useful energy

Many exothermic chemical reactions are used to provide energy in a wide range of situations. Table 4.7.1 provides four everyday examples.

TABLE 4.7.1 Four examples of everyday exothermic chemical reactions

Combustion engines provide energy in a petrol-fuelled car
Energy is provided in the reaction that occurs in car engines due to the combustion of octane. The heat produced causes gases to expand and push the pistons in the car engine. The reaction can be controlled by changing the flow of petrol (octane) and the amount of oxygen available. Chemical reaction octane (C_8H_{18}) + oxygen (O_2) → carbon dioxide (CO_2) + water (H_2O) + HEAT
Bunsen burners provide a safe heat source
Bunsen burners provide energy because they burn either methane (CH_4) gas or liquefied petroleum gas (LPG), which is a mixture of propane (C_3H_8) and butane (C_4H_{10}). If the airhole on the Bunsen burner is open, more oxygen is available, and more heat is produced by the flame. Chemical reaction methane (CH_4) + oxygen (O_2) → carbon dioxide (CO_2) + water (H_2O) + HEAT
Exothermic reactions cause airbags to rapidly inflate
Safety airbags in cars use incredibly fast exothermic reactions. They produce a large volume of gas very quickly. The heat generated in the reaction helps to inflate the airbag as the heat makes the particles of gas separate more quickly. However, when airbags go off accidentally, there is a risk of burns caused by contact with the hot chemicals. Silicon dioxide (SiO_2) is also in the mixture of chemicals because this will react with potentially harmful products of these reactions to produce two safer products: potassium silicate (K_2SiO_3) + sodium silicate (Na_2SiO_3).
Chemical reactions 1 sodium nitride (Na_3N) → sodium (Na) + nitrogen (N_2) 2 sodium (Na) + potassium nitrate (KNO_3) → potassium oxide (K_2O) + sodium oxide (Na_2O) + nitrogen (N_2) 3 potassium oxide (K_2O) + sodium oxide (Na_2O) + silicon dioxide (SiO_2) → potassium silicate (K_2SiO_3) + sodium silicate (Na_2SiO_3)

Batteries provide electrical energy

Batteries use chemical reactions to produce electrical energy. An example of this is the lithium ion used to power electric vehicles. Lithium carbide (LiC_6) reacts with cobalt oxide (CoO_2) and the reaction generates an electric current.
When the batteries in the car are recharged, the reaction is reversed, and the electric energy is converted back to stored chemical energy.
Chemical reaction
lithium carbide (LiC_6) + cobalt oxide (CoO_2) → graphite (C) + lithium cobalt oxide ($LiCoO_2$) + ENERGY

SC 3 CHECK YOUR UNDERSTANDING

Name one common household use of the energy output from a combustion reaction.

Lesson review

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

1. Explain the difference between reactants and products in a chemical reaction.
2. List the four main energy outputs from chemical reactions and one example of each form of energy when it is harnessed for practical use.
3. List the main steps in an experiment that tests whether dissolving ammonium nitrate in water is endothermic or exothermic.
4. Compare the reactants and products of the combustion of sodium metal in oxygen and the reaction with sodium with an acid.
5. Compare the uses of energy outputs from combustion reactions with the movement of energy in photosynthesis.
6. Categorise the following reactions into combustion, corrosion, respiration, photosynthesis, or acid with reactive metals.
   a. A strip of magnesium is placed into a solution of hydrochloric acid.
   b. Gases are produced by a plant kept in complete darkness.
   c. Green copper carbonate forms on the copper domes on the roof of Flinders Street Station.

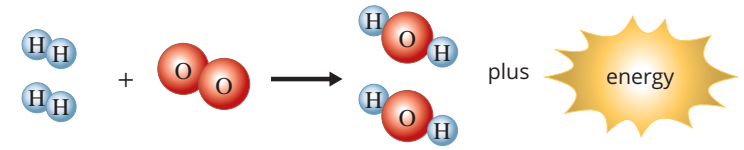


4.8 Representing chemical reactions

Lesson overview

A chemical is a substance with a fixed composition. Therefore, any pure substance is a chemical. When chemicals undergo chemical changes, new substances are made, which are called the products of the reaction. In a chemical reaction, the arrangement of the particles in substances involved changes to make the new substances.

In this lesson, you will learn how chemical reactions can be represented, including word equations, symbol equations and models that show the arrangement of particles (see Figure 4.8.1 as an example).



hydrogen + oxygen → water (word equation)

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ (symbol equation; the numbers before the formulas show the number of molecules that react, letters in brackets are state symbols)

FIGURE 4.8.1 The reaction of hydrogen and oxygen to produce water represented in three different ways

SC 1 I can write word equations to summarise chemical reactions

Learning intention

To understand how chemical reactions are represented by scientific models

Success criteria

SC 1: I can write word equations to summarise chemical reactions.

SC 2: I can describe the changes occurring in a chemical reaction from a symbol equation with familiar substances.

SC 3: I can represent changes in the structure of molecules in a simple chemical reaction using two- and three-dimensional models.

Word equations

Word equations are a simple way to show what has happened in a chemical reaction.

The reactants are shown on the left and the products are shown on the right.

An arrow (→) is placed between the reactants and products and represents the change between the chemicals at the start (reactants) and the chemicals at the end (products).

Reversible reactions

Most chemical reactions only go one way; that is, they are irreversible reactions. The reactants are converted into the products. However, there are some chemical reactions that are reversible. This means that the products can convert back to the reactants.

If a reaction is reversible, this arrow ⇌ is used.

Examples of word equations

- Sodium and water
  sodium + water → sodium hydroxide + hydrogen
- Production of ammonia
  nitrogen + hydrogen → ammonia
- Reaction of an acid and alkali (base)
  hydrochloric acid + sodium hydroxide → sodium chloride + water
- Reaction of an acid and a carbonate
  sulfuric acid + calcium carbonate → calcium sulfate + carbon dioxide + water

SC 1 CHECK YOUR UNDERSTANDING

Write the word equation for the reaction of sodium with chlorine to form sodium chloride.

SC 2 I can describe the changes occurring in a chemical reaction from a symbol equation with familiar substances

Symbol equations

Symbol equations can be used to represent the changes that occur in a chemical reaction. The chemicals are represented by their formulas, which are made up from the atomic symbols of the elements.

Numbers of atoms in chemical formulas

KEY TERM

molecule a group of atoms joined together with chemical bonds

Chemical formulas show the number of each type of atom in a substance.

For example, oxygen gas has the formula O_2 because it contains two oxygen atoms in each **molecule**.

Carbon dioxide has the formula CO_2 because it contains one carbon (C) atom and two oxygen atoms. Calcium carbonate has the formula $CaCO_3$ because for each calcium (Ca) atom it contains one carbon atom and three oxygen atoms.

Numbers of atoms in chemical equations

Because atoms are not created or destroyed in a chemical reaction, the total number of atoms does not change. This means that the numbers of atoms on the reactant side and the product side of the equation must be the same. (This is called a balanced chemical equation.)

To make sure that this is the case, numbers can be placed before a formula in an equation to show that there is more than one of that substance taking part in the reaction.

For example, the symbol equation for the reaction of hydrogen and oxygen to form water is: $2H_2 + O_2 \rightarrow 2H_2O$. The number 2 before the hydrogen (H_2) and the number 2 before the water (H_2O) are there because each oxygen molecule needs two hydrogen molecules for the reaction to happen. So $2H_2$ means two molecules of hydrogen—a total of four hydrogen atoms. So $2H_2O$ means two molecules of water—a total of four hydrogen atoms and two oxygen atoms (Figure 4.8.1).

State symbols in chemical equations

To show the state of a chemical in a chemical reaction, the letters (g), (l) or (s) can be used to show if a chemical is in the form of a gas, liquid or solid. If the chemical is in the form of a solution in water, the letters (aq) are used, which stands for aqueous, which means containing water.

For example, the chemical reaction between solid sodium and water to produce hydrogen gas and a solution of sodium hydroxide can be written as:

$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

Other examples include:

- The combustion of methane: methane + oxygen → carbon dioxide + water
  $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$
- Photosynthesis: carbon dioxide + water → glucose + oxygen
  $6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$
- Formation of carbonic acid: carbon dioxide + water ⇌ carbonic acid
  $CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$

SC 2 CHECK YOUR UNDERSTANDING

Describe the changes occurring in the reaction represented by the symbol equation:

$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$

SC 3 I can represent changes in the structure of molecules in a simple chemical reaction using two- and three-dimensional models

Models can be used to represent the changes to atoms and molecules that occur in a chemical reaction.

2D modelling of chemical reactions

Two-dimensional (2D) models use diagrams of atoms and molecules to show changes in the arrangement of the atoms. Symbol equations can show which atoms are present, how many atoms there are and which atoms are joined with others. The models can actually show how the atoms are joined at the start (in the reactants) and at the end (in the products).

Combustion of carbon

Carbon dioxide is formed as one atom of carbon is combined with the two atoms in a molecule of oxygen. Figure 4.8.2 represents this reaction as a diagram.

The symbol equation is:

$C + O_2 \rightarrow CO_2$



FIGURE 4.8.2 A 2D model of the reaction: carbon + oxygen → carbon dioxide

Combustion of methane

Figure 4.8.3 shows the 2D model, word equation and symbol equation for the combustion of methane. The molecules in the 2D model are represented with coloured atoms joined together. Note that there are two molecules of oxygen and two molecules of water. If the extra molecules were not included, the numbers of atoms on each side of the equation would not be the same, and the equation would not be balanced.

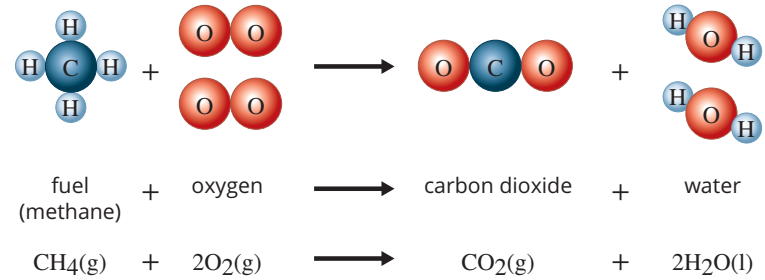
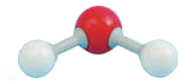


FIGURE 4.8.3 The combustion of methane represented as a 2D model, word equation and symbol equation

3D modelling of chemical reactions

Using a three-dimensional (3D) model is a more realistic representation because real molecules are 3D. The arrangement of the atoms, how they are bonded together and the shape of the molecule can be shown using 3D models (Table 4.8.1).

TABLE 4.8.1 A list of common chemicals and their 3D models

Water (H_2O)	Oxygen gas (O_2)	Ammonia (NH_3)
		
Carbon dioxide (CO_2)	**Nitrogen gas (N_2)**	**Hydrogen gas (H_2)**
		

To observe the change in the 3D structure of a chemical reaction, an example of the production of ammonia using 3D models is given in Figure 4.8.4. The symbol equation for this reaction is:

$N_2 + 3H_2 \rightarrow 2NH_3$

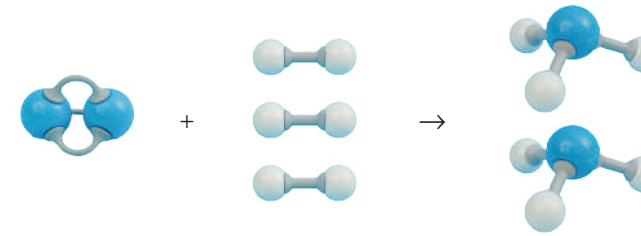


FIGURE 4.8.4 A 3D model of the reaction of nitrogen and hydrogen gases to produce ammonia

SC 3 CHECK YOUR UNDERSTANDING

Here is a 3D model of ethene. The black balls are carbon atoms and the white balls are hydrogen atoms. Using this information, write the chemical formula of ethene.



Lesson review

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

1 Write the word equation for the reaction between silver and hydrogen sulfide that forms silver sulfide and hydrogen gas.

2 Photosynthesis has the following chemical equation.

$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$

- **a** Determine how many water molecules are used in the reaction.
- **b** List the products of the reaction.
- **c** Calculate how many oxygen atoms are present in the reactants.

3 Chlorine gas (Cl_2) and phosphorus trichloride (PCl_3) react to form phosphorus pentachloride (PCl_5) as represented in the reaction:

$Cl_2 + PCl_3 \rightleftharpoons PCl_5$

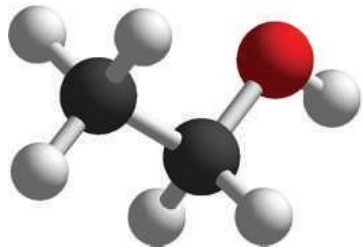
Using this chemical equation, determine whether the reaction is reversible or irreversible.

4 The reaction between magnesium (Mg) and hydrochloric acid (HCl) forms magnesium chloride ($MgCl_2$) and hydrogen gas (H_2).

$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

- **a** Write the word equation for this reaction.
- **b** Identify the reactants and products in the word equation.
- **c** Explain why it is important to balance chemical equations.
- **d** Compare the clarity of the word equation with that of the balanced chemical equation for this reaction.

5 The 3D model of ethanol is provided below. Determine the chemical formula of ethanol using the model. Black balls are carbon, red balls are oxygen and white balls are hydrogen.



6 Draw the 2D model representation of the following chemical reaction.

iron + hydrochloric acid → iron chloride + hydrogen

$Fe(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$

4.9 Combustion reactions

Learning intention

To understand that combustion reactions produce heat and light

Success criteria

SC 1: I can identify the inputs required for a combustion reaction to occur.

SC 2: I can describe the outputs of a range of combustion reactions.



FIGURE 4.9.1 Combustion reactions produce the heat to cook on a barbecue.

KEY TERM

combustion a chemical reaction in which a substance burns in oxygen gas to produce light and heat

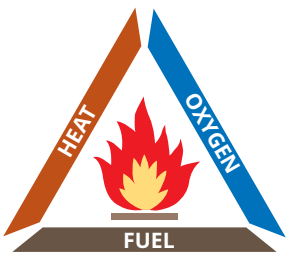


FIGURE 4.9.2 The fire triangle illustrates the three key components for starting a fire.

Lesson overview

There are many types of chemical reaction, but combustion is one that has probably had the most impact on humans. Without combustion, survival in cold climates would have not been possible. In addition, it was combustion reactions that created the heat required to extract metals, such as copper and iron, used to make early tools.

Nowadays, combustion is used in many aspects of everyday life, from cooking (Figure 4.9.1), heating and providing entertainment, to firework displays.

In this lesson, you will learn about what is required for a combustion reaction to take place, what is produced, and how you can safely use combustion reactions.

SC 1 I can identify the inputs required for a combustion reaction to occur

Combustion reactions always involve a substance burning in oxygen. The substance burning is called the fuel, and the oxygen can be provided by the atmosphere (which contains 21% oxygen).

To start a combustion reaction, an energy input is required, normally in the form of heat. Ignition sparks, flames or high temperatures can all start a combustion reaction.

So, the three things required for combustion are:

- fuel
- oxygen
- heat.

These are referred to as the fire triangle (Figure 4.9.2).

If one of the three are missing, combustion will not start. If you remove one from a fire that has already started, the combustion reaction will not continue. However, a combustion reaction is an exothermic reaction, which means that it releases heat to environment, so once it is started, it is very hard to remove heat!

The chemistry of flames

Flames occur when a gas is burning in air (which contains oxygen). The flame front (or combustion zone) is where the chemical reaction takes place. The reaction gives off heat and light.

The heat from this reaction moves outwards into the environment, but also inwards, to the core of the flame, where there is unburnt gas. This heat ignites this gas and it combusts in the flame front. Hence, a flame will continue to burn as long as there is enough oxygen and the fuel does not run out.

When observing a burning candle, you can see the core closest to the fuel (the wick). The flame front surrounds the core, causing a yellow-orange flame where oxygen reacts with the fuel (Figure 4.9.3). You can also see the core and the flame front when using a Bunsen burner.

Watching a flame can be a calming experience that focuses the mind. The seemingly random, glowing and flickering movement of flames can be used in mindfulness practice. Flames often have symbolic meaning; for example, the Olympic flame (Figure 4.9.4), religious services and other traditional ceremonies.

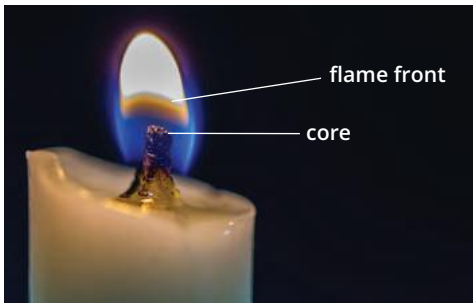


FIGURE 4.9.3 A candle flame has multiple colours, representing the core (blue) and the flame front (yellow-orange).



FIGURE 4.9.4 Cathy Freeman lighting the flame for the 2000 Sydney Olympics

Scifile

Fireworks

Fireworks are a spectacular example of combustion reactions. Different chemicals react to produce bright colours and loud bangs, making celebrations more exciting and visually stunning.



FIGURE 4.9.5 Rocket fuel burns very quickly, producing huge forces.

Fuels

A fuel is any substance that takes part in reactions that release energy. Different fuels are chosen depending on the use of energy.

Rockets need large amounts of energy very quickly. Fuels such as hydrogen are used to produce the huge amounts of energy required to accelerate the rocket enough to overcome the forces of gravity (Figure 4.9.5).

In other situations, the aim is for a fuel to provide a smaller amount of energy over a long period time. A slower burning fuel can be used in this situation. Olympic torches use a mixture of butane and propane. The physical design of the torches protects the flames from wind and rain, and some torches are even designed to stay alight under water.

When the Olympic flame travels in aircraft, miners' lamps, based on the Davy lamp (Figure 4.9.6), originally designed in 1815, are used to reduce risk. These lamps use a paraffin-based fuel and are able to provide light without the risk of an exposed flame, which is very important in a mine where flammable gases are often present in the atmosphere.



FIGURE 4.9.6 A traditional miners' Davy lamp

Common fuels and their uses

Commonly used fuels include:

- Petrol: used for car engines. Contains octane (C_8H_{18}).
- Natural gas: used for cooking, the generation of electricity, heating and fuels some buses. Contains methane (CH_4).
- Alcohol: used for camping stoves, can be added to petrol. It can be produced from plant material (known as a biofuel) or from crude oil. Contains ethanol (C_2H_5OH).

- Coal: used for the generation of electricity in coal-fired power stations and heating. Contains impure carbon (C).
- Diesel: used for trucks, buses and other heavy vehicles. Contains larger molecules containing hydrogen and carbon (e.g. $C_{12}H_{26}$).
- Hydrogen gas: used in rocket engines and some welding equipment.
- Wood: used for heating and cooking. Contains a mixture of carbon-based chemicals, including cellulose.
- Liquefied petroleum gas (LPG): used for some cars and barbecues. Composition varies but often contains a mixture of butane (C_4H_{10}) and propane (C_3H_8).

SC 1 CHECK YOUR UNDERSTANDING

List the three main inputs required for a combustion reaction.

SC 2 I can describe the outputs of a range of combustion reactions

Products of combustion reactions

Combustion reactions involve oxygen combining with the substance that is burning. For example, when magnesium burns, it forms magnesium oxide:

magnesium + oxygen → magnesium oxide

The symbol equation for this reaction is:

$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

Combustion of elements

Predicting the products for the combustion of elements is relatively easy. There is normally only one product, which is the oxide of the element being combusted. For example:

iron + oxygen → iron oxide	$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$
coal (impure carbon) + oxygen → carbon dioxide	$C(s) + O_2(g) \rightarrow CO_2(g)$
sulfur + oxygen → sulfur dioxide	$S(s) + O_2(g) \rightarrow SO_2(g)$

Combustion of compounds

When a chemical compound is combusted, the elements in the compound combine with oxygen to form new compounds.

Most fuels used in daily life are carbon based. This leads to the fact that carbon dioxide (and at times carbon monoxide) is almost always produced as a result of the combustion of fuels. Many of these fuels contain hydrogen, and when oxygen is added to hydrogen, water is formed.

Examples of the combustion of compounds:

methane + oxygen → carbon dioxide + water	$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$
propane + oxygen → carbon dioxide + water	$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$
octane + oxygen → carbon dioxide + water	$2C_8H_{18}(g) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$

Incomplete combustion

Fuels need oxygen to burn—sometimes a lot of oxygen. For example, to burn 1 L of octane in petrol, 2000 L of oxygen is needed. This is approximately 10 000 L of air.

If not enough oxygen is supplied to the combustion reaction, incomplete combustion can occur. This can mean that instead of carbon dioxide (CO_2) being produced, carbon monoxide (CO) is produced by the reaction.

Two examples of incomplete combustion:

1 octane + oxygen → carbon monoxide + water

$2C_8H_{18}(g) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(l)$

2 propane + oxygen → carbon monoxide + water

$2C_3H_8(g) + 7O_2(g) \rightarrow 6CO(g) + 8H_2O(l)$

Carbon monoxide is a poisonous gas. If absorbed into the body, it prevents oxygen being transported around the body in the blood. It is also colourless and odourless, which makes it even more dangerous because people can be breathing it in without realising it.

More than 400 people die of carbon monoxide poisoning each year in the USA. The numbers are much lower in Australia, partly because it is a legal requirement to have an air vent placed next to any installed gas point. However, carbon monoxide is still a serious health risk, especially in the winter, as people fail to service their gas appliances and seal air vents to keep in the heat.

Carbon itself can also be produced as a result of incomplete combustion (Figure 4.9.7). This can be seen in the form of black smoke, which contains particles of unburnt carbon particles. This is also why the flame on a Bunsen burner is smoky when the airhole is closed.



FIGURE 4.9.7 Black smoke is often the result of incomplete combustion.

SCIENCE IN SOCIETY

Controlled cool-burn fires

In Australia, bushfires are an example of combustion. For a combustion reaction to occur, three things are needed: a fuel, oxygen and heat. When these things come together the fuel reacts with oxygen to produce heat, light and new substances. In a bushfire, wood, leaves and dead vegetation combust in the presence of oxygen. Complete combustion, where carbon dioxide and water vapour are the products, rarely occurs in a bushfire. Instead, incomplete combustion, where carbon monoxide, carbon (soot, charcoal), and other carbon-based substances are the products, occurs.



FIGURE 4.9.8 A photo of the devastation outside Marysville, Victoria, after the Black Saturday bushfires

Bushfires can be devastating (Figure 4.9.8). The Black Summer bushfires (2019–2020), Black Saturday bushfires (7 February 2009) and Ash Wednesday bushfires (16 February 1983) are just a few of the catastrophic fires that lead to fatalities, loss of properties and livestock as well as millions of acres of forests and crops destroyed in Australia. However, fires have been always part of the Australian landscape. With a concerted effort to understand First Nations fire management, evidence shows that controlled cool burns benefit the environment. These burns play a significant role in clearing dead vegetation and promoting new plant growth. Additionally, some plant species require the smoke and heat from these burns for seed germination. The substances in smoke that trigger seed germination, known as karrikins, have been recently discovered.

Karrikins are formed by the incomplete combustion of the carbohydrates in the burning vegetation. Karrikin comes from the word 'smoke' in the Noongar language, spoken by First Nations people in southern Western Australia. Karrikinolide (Figure 4.9.9) was the first of the karrikin substances discovered in 2009. After a controlled cool fire has burnt the forest, karrikinolide settles on top of the soil until it rains. The rain washes it down into the soil where the seeds are residing. The karrikinolide molecules trigger the seed to germinate, where the plant undergoes its growth cycle.

One example of an Australian native plant that requires karrikinolide to germinate their seeds is the pink flannel flower, *Actinotus forsythii* (Figure 4.9.10).

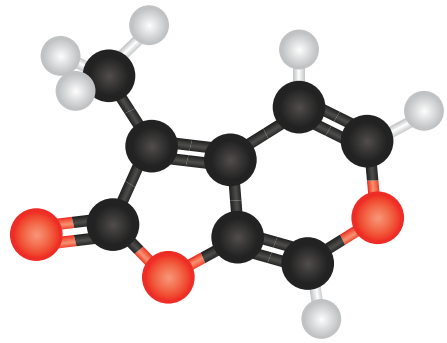


FIGURE 4.9.9 A 3D model of the karrikinolide molecule. Black is carbon, white is hydrogen and oxygen is red.



FIGURE 4.9.10 The pink flannel flower, *Actinotus forsythii*, requires karrikinolide for their seeds to germinate.

SC 2 CHECK YOUR UNDERSTANDING

Name two common outputs of a complete combustion reaction of a carbon-based fuel.

Lesson review

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

1. Explain why combustion reactions are not endothermic reactions.
2. Describe the inputs required for the combustion of propane (C_3H_8) in a barbecue grill.
3. Using the fire triangle (Figure 4.9.2) and your knowledge of combustion, explain why windy weather makes it difficult to manage a bushfire.
4. The reaction for the combustion of propane is written as:

   $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$

   When propane is combusted, it is not possible to observe liquid water being produced. Explain why this might be the case.
5. Compare the outputs of complete combustion with those of incomplete combustion.

4.10 Chemical energy

Lesson overview

Kinetic energy (energy of movement), heat energy, sound and light are all observable forms of energy. Other forms of energy are less visible but still cause changes. For example, electrical energy can be transformed into light in a torch, elastic energy stored in a coiled-up spring can be transformed into kinetic energy when released, and gravitational potential energy is transformed into kinetic energy when an object falls.

Chemical energy is a stored form of energy. When it is released, it can be transformed into other forms, such as heat, light and electricity. Because it is stored and has the potential to transform, chemical energy is often referred to as chemical potential energy. All chemicals contain chemical potential energy, but different substances store different amounts.

In this lesson, you will learn about chemical energy: what it is, how it can be released, and how different chemicals contain different amounts of chemical energy.

Learning intention

To understand that during a chemical reaction energy is released or absorbed

Success criteria

SC 1: I can describe the concept of chemical energy.

SC 2: I can describe how chemical energy is transformed in a range of living and non-living systems.

SC 3: I can compare the energy content of fuels and food.

SC 1 I can describe the concept of chemical energy

All chemicals contain chemical energy, but because this energy is not visible, it can be difficult to describe. When coal is burnt, it releases heat energy. When sugar is eaten, it provides energy for the body. But what exactly is chemical energy, and how does it work?

Chemical energy and particles

In just about all substances, the atoms that make up the substances are joined together. The forces that join the atoms together are called **chemical bonds** (refer to examples in Figure 4.10.1). Chemical energy is stored in these chemical bonds.

KEY TERM

chemical bond a force of attraction that joins atoms together

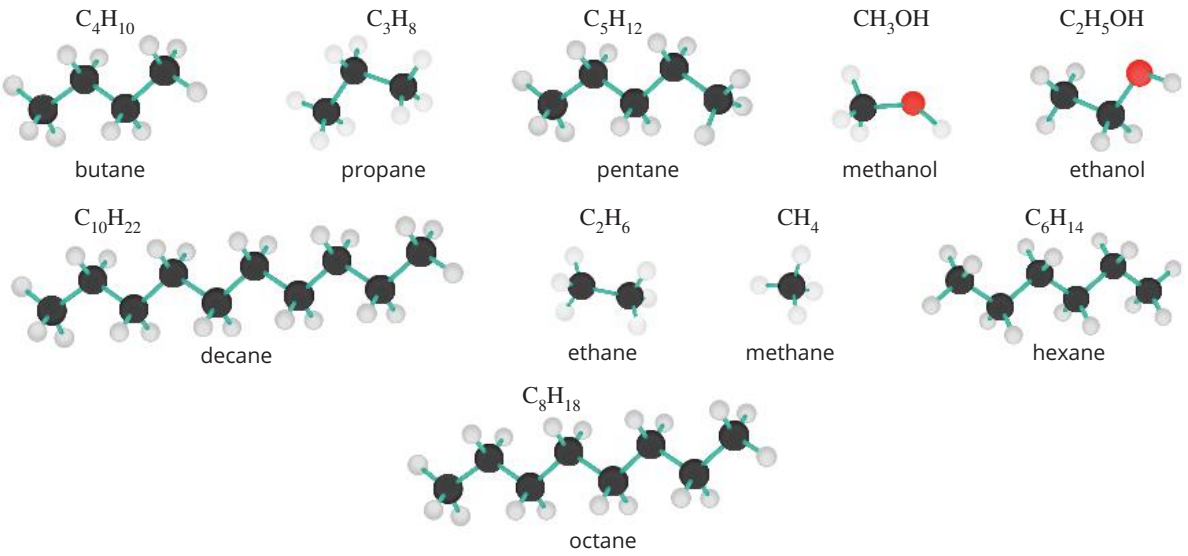


FIGURE 4.10.1 Many fuels contain carbon and hydrogen atoms joined together by chemical bonds.

It is still hard to imagine how a force can store energy, so let's go back to what stored energy means.

KEY TERM

potential energy energy stored by an object (because of its position or chemical structure) that can be transformed into another form of energy

Stored energy

Stored energy (or **potential energy**) can be thought of as 'energy waiting to happen'. Imagine you have just eaten a big chocolate bar and drunk a can of a sugary soft drink. You have lots of energy but may be sitting in a science class and you cannot use your energy to be physically active. It is as though you are bonded together with others in your class, but you have plenty of energy waiting to be used! That is a bit like chemical potential energy.

At the end of the lesson – freedom! You can move about. The stored energy is now being used up, and the result is movement, maybe some heat and probably some sound. This is like the observable energy released to the surroundings. Your energy, though, is reducing.

This is not a perfect analogy, but it might help to appreciate how chemical bonds can store energy in chemicals for use later.

Chemical energy is invisible

Although you cannot see or feel chemical energy itself, scientists can measure how much energy is released when a substance takes part in chemical reactions. The apparatus used to measure the amount of energy released by a substance in a chemical reaction is called a calorimeter. Figure 4.10.2 demonstrates a basic set-up of a calorimeter.

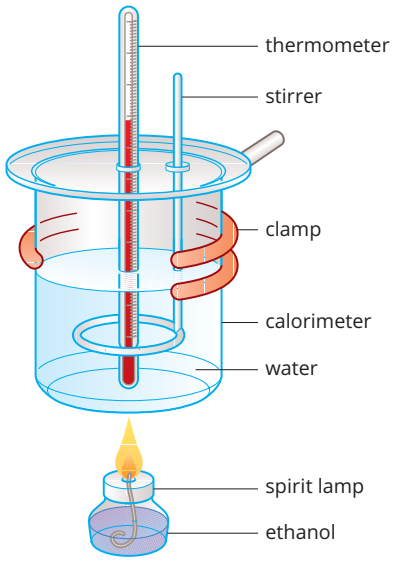


FIGURE 4.10.2 A calorimeter can be used to measure the amount of heat release by a chemical reaction, in this case the combustion of ethanol.

The chemical energy of substances can be compared by looking at the amount of chemical energy that can be produced by the combustion of exactly 1.00 g of the substance.

The unit for energy is the joule (J), or kilojoule (kJ) where one kilojoule is 1000 joules. One kilojoule is approximately the amount of energy required to increase the temperature of 200 mL water from 20°C to 21°C.

See Table 4.10.1 for the energy content for some chemicals.

TABLE 4.10.1 Energy content for some substances

Substance	Chemical energy per gram (kJ/g)
methane (natural gas)	55.6
glucose (a form of sugar)	15.6
hydrogen gas	141.9

SC 1 CHECK YOUR UNDERSTANDING

Define chemical energy.

SC 2 I can describe how chemical energy is transformed in a range of living and non-living systems

The process of energy changing from one form to another is called **energy transformation**. Chemical energy stored in chemicals can be transformed to heat energy in exothermic reactions. As the energy is transformed into heat, the amount of stored chemical energy reduces.

This is a bit like using money to buy food at the supermarket. As you gain food at the checkout, your supply of money is reduced.

KEY TERMS

energy transformation the transformation of one form of energy into another form of energy

system a collection of interconnected components

Conservation of energy

The key scientific law that applies to energy transformation is the law of conservation of energy. This states that energy cannot be created or destroyed, just transferred or transformed from one form to another. Therefore, the total amount of energy in a system will stay the same.

In chemical reactions, this means that if more heat energy is released, the reactants lose an equivalent amount of stored chemical energy.

Energy in systems

A **system** is several components that are connected together. A chemical reaction is a system because the reactants (the inputs to the system) are connected to the products (the outputs of the system). The energy inputs and outputs are also connected to what is happening in the chemical reaction.

For example, the combustion of methane (natural gas) is a system. A Bunsen burner is a suitable example of this system (Figure 4.10.3).

The chemical reaction starts with the reactants methane (CH_4) and oxygen (O_2) and finishes with the products water (H_2O) and carbon dioxide (CO_2):

methane + oxygen → water + carbon dioxide + HEAT ENERGY

CHEMICAL ENERGY OF REACTANTS = CHEMICAL ENERGY OF PRODUCTS + HEAT ENERGY

Heat energy is released, so the chemical energy is being transformed.

This means that the combined chemical energy of the water and carbon dioxide must be less than the combined chemical energy of the methane and oxygen.

Other examples of energy transformation in chemical systems are described in Table 4.10.2.



FIGURE 4.10.3 This Bunsen burner is burning natural gas (methane) to produce carbon dioxide, water and heat energy.

TABLE 4.10.2 Energy transformation examples in chemical systems

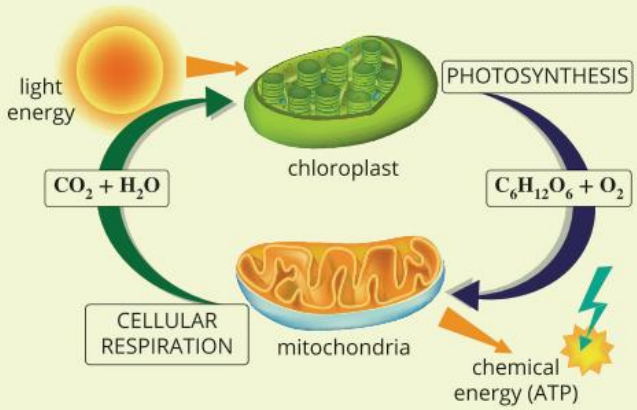
Cellular respiration

Respiration is the chemical reaction that releases energy in cells in the mitochondria. The equation for the reaction is:

glucose + oxygen → carbon dioxide + water + ENERGY (ATP)

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

Chemical energy in cells is stored in a chemical called ATP (adenosine triphosphate). ATP then provides the energy required for a range of functions of the body, such as muscle movement.



Electrochemical cells

Many chemical reactions can be used to produce electrical energy. One example is hydrogen fuel cells that use the reaction of hydrogen and oxygen to produce water.

hydrogen + oxygen → water + ELECTRICAL ENERGY

$2H_2 + O_2 \rightarrow 2H_2O$

Hydrogen fuel cells can power spacecraft and artificial satellites, as well as electric vehicles and even boats and submarines.



Combustion

Combustion reactions are commonly used to produce heat energy via exothermic reactions.

Ethyne (C_2H_2) gas, sometimes called acetylene, is a fuel with a very high energy content. It has been used in coastal lighthouses and mining headlamps but is probably best known for use in welding tools.

The gas is mixed with pure oxygen to make oxyacetylene, which allows for the flame to be extremely hot (more than 3000°C), enough to melt just about all metals.

ethyne + oxygen → carbon dioxide + water + HEAT ENERGY

$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$



Bioluminescence: Fireflies and glow worms

Some animals use light to attract potential food (glow worms) or potential mating partners (fireflies). The reaction involves a chemical called luciferin, normally reacting with oxygen. A chemical called luciferase helps to speed up the reaction. The reactions are complex, but can be summarised as shown.

luciferin + oxygen → oxyluciferin + carbon dioxide + LIGHT ENERGY



Energy transformation

In the examples in Table 4.10.2, the stored chemical energy is transformed into forms of energy that can be used. It is important to recognise that not all the stored chemical energy can be transformed to useful forms. Any energy transformation will involve some energy being 'lost' from the system into the surroundings, often as unwanted forms such as heat or sound energy. As a result, no energy transfer is 100% efficient.

SC 2 CHECK YOUR UNDERSTANDING

Classify the transformation of chemical energy in an electric car motor.

SC 3 I can compare the energy content of fuels and food

Energy content of fuels

Fuels are chosen for different uses based on their properties.

Fuels that are gases, such as methane and hydrogen, tend to burn very easily; however, they can be dangerous to store because there is a risk of explosion. Solid fuels, such as coal or wood, might be safer and easier to transport, but might not burn fast enough if high amounts of energy are required. However, if energy is required for a longer period of time, such as for lighting or heating a home, a slower burning fuel might be more useful.

One way to decide on the best fuel to use is to compare the energy content that can be extracted from different fuels.

Table 4.10.3 provides a list of various fuels and the energy produced from combustion. The units used for fuels are normally megajoules (1 million joules) per kilogram of the fuel.

TABLE 4.10.3 The chemical energy of various fuels, given as megajoules (MJ) per kilogram (kg)

Substance	Chemical energy per kilogram (MJ/kg)
methane (present in natural gas)	55.6
octane (present in petrol)	47.8
ethanol (a form of alcohol)	29.7
glucose (a form of sugar)	15.6
hydrogen gas	141.6
wood	approximately 16
coal	approximately 25
diesel fuel	42–46
LPG (liquefied petroleum gas)	46–51

Scifile

Water in space

Astronauts who undertook the Apollo space missions obtained their water to drink from the hydrogen–oxygen fuel cells. These fuel cells created electricity and the product of that combustion reaction is water, which is then collected and drunk by the astronauts in space.



FIGURE 4.10.4 A food label that shows the energy content per 100 g of the food

Energy content of food

In Australia, the energy content of foods is normally given on nutrition labels in kilojoules (kJ) per 100 g of the food (Figure 4.10.4).

Table 4.10.4 provides approximate energy content of a range of foods. The units are kilojoules per 100 g of the food. For a 14-year-old, the daily recommended intake is around 11 000 kJ for boys and 10 000 kJ for girls.

TABLE 4.10.4 The chemical energy of various foods, given as kilojoules per 100 g of food

Food	Chemical energy per 100 grams (kJ/100 g)
raw apple	200
dried apple	1100
iced chocolate cake	1600
corn chips	2100
boiled white rice	526
pappadam (fried)	1500
pappadam (microwave)	1300
peanut butter	2500
margarine spread (salted)	2600
butter	3100
vegetable oil	3390
regular ice cream	770
table sugar	1600
white bread	1020
white bread toasted	1264
Gatorade sports drink	103
Red Bull drink	179

DISCOVER MORE

Calories

In the USA, the energy values for foods are given in calories. However, the calorie unit can be a bit confusing. This is because the word 'calorie' is often used when we mean a kilocalorie (kcal). So, when you look at a food label, it will often give the energy content with the abbreviated 'kcal', but is normally called just Calories (with a capital C)!

Therefore, it is best to stick to using kilojoules as the unit for energy, which is part of a globally recognised system of units. 1.0 kilojoule (kJ) = 0.239 kilocalories (kcal).

SC 3 CHECK YOUR UNDERSTANDING

Name one fuel and one food item with a high energy content by referring to Tables 4.10.3 and 4.10.4.

Lesson review

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

1. Identify one example of the transformation of chemical energy to another form in a living system.
2. Name the apparatus that measures the amount of heat released by a chemical reaction.
3. Compare the energy content of ethanol and octane and suggest why cars, which need a lot of energy, are run on octane rather than pure ethanol.



4. Describe how you would compare the energy content of two different foods by using the packaging as well as an experimental method.
5. The chemical energy of aviation fuel is 43.5 MJ/kg, which is very similar to diesel and petrol fuels. A Boeing 737 holds 25 000 kg of aviation fuel for a flight. Calculate the amount of chemical energy contained in this amount of aviation fuel.

4.11 Making an effective cold pack

Learning intention

To be able to select and use appropriate equipment to investigate which chemical is the most effective for a cold pack that uses an endothermic reaction

Success criteria

SC 1: I can plan an experiment to test the effectiveness of a cold pack.

SC 2: I can select and use equipment correctly to record temperature change during an endothermic reaction.

SC 3: I can evaluate the quality of data used to write a conclusion relating to temperature change in a chemical reaction.



FIGURE 4.11.1 Instant cold packs use endothermic reactions.

Introduction

Cold packs are applied to sporting and other injuries to decrease the blood supply to an injured area. They reduce bruising and swelling that may result from an injury by cooling the area, which reduces bleeding. Some commercially available cold packs depend on an endothermic reaction (Figure 4.11.1). Often this is the reaction of a chemical as it dissolves into water.

In this practical investigation, you will test a range of chemicals to discover which would be the most effective for use in a cold pack. The temperature changes may not be very large, so you will need to devise accurate ways to measure the temperatures in the experiment.

Background

The endothermic reactions used in most instant cold packs involve chemicals dissolving in water. As the chemicals dissolve, their particles separate from each other, which requires energy.

This process absorbs heat energy from the surroundings and transforms it into the chemical energy. As a result, the temperature of the surrounding environment (such as an injured part of the body) decreases as heat is absorbed into the chemicals in the cold pack.

You can choose to answer one of these questions.

Question 1: Which chemical will produce the greatest temperature decrease?

Question 2: Which chemical will produce the quickest temperature decrease?

Aim

To carry out an experiment that will identify which chemical is the most effective for use in a cold pack

Materials

The chemicals that you are going to test are:

- ammonium chloride (NH_4Cl)
- potassium iodide (KI)
- urea (CH_4N_2O)

You will have access to some or all of the following:

- thermometers
- electronic balances
- glass rods
- glass beakers (100 mL or 250 mL)
- measuring cylinders (50 mL or 100 mL)
- polystyrene cups
- stopwatches
- plastic teaspoons.

Assessment of risk

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

SAFETY NOTE

- Wear safety glasses throughout the experiment and avoid skin contact with the chemicals being used.

Method

Write a step-by-step method for your investigation. Include equipment and quantities of chemicals that you will use.

GO TO
Toolkit sections 2.1, Reducing risk and 2.5, Selecting equipment for accurate measurement

Results

Record your results in a suitable results table.

Conclusion

Use evidence from your results to explain which is the most effective chemical to use to make a cold pack.

Evaluation

Evaluate your practical investigation by answering the following questions.

1. Comment on the quality of the evidence that you used to identify the most effective chemical. Use direct evidence from your results to justify your answer.
2. Describe at least two modifications to your method that you either carried out or could apply to your method. Explain how these modifications would improve the reliability or the validity of your results.

GO TO
Toolkit sections 4.2, Evaluating validity and 4.3, Evaluating reliability

4.12 Rapid chemical testing in sport

Learning intention

To understand how world views relating to fairness in sport have led to the development of rapid chemical tests to identify performance-enhancing drugs

Success criteria

SC 1: I can describe the effects of some performance-enhancing drugs.

SC 2: I can explain how performance-enhancing drugs are detected in the body.

SC 3: I can explain how rapid chemical tests are used to identify performance-enhancing drugs.



FIGURE 4.12.1 A drug testing station at the Beijing Olympics



FIGURE 4.12.2 Steroids can be used to boost muscle development in weightlifters.

Lesson overview

In sports, it is important to make sure that all athletes have equal access to a fair competition. Everyone should have an equal chance to compete, and win, based on their skills and talents, without using any unfair advantages such as drugs to enhance their performance. Using performance-enhancing drugs, also known as doping, can give some athletes an unfair advantage over others. This goes against the principles of fair competition.

In this lesson, you will learn about how world views relating to fairness in sport have led to the development of rapid chemical tests to identify performance-enhancing drugs.

SC 1 I can describe the effects of some performance-enhancing drugs

A performance-enhancing drug (PED) is a substance or method that is used by athletes to improve their performance in sports or athletic competitions. PEDs are intended to enhance physical abilities, such as strength, speed, endurance, agility or recovery, beyond what can be achieved through natural training and conditioning.

PEDs can take various forms, including drugs, hormones, stimulants, diuretics, blood doping agents, and other substances or methods that are used to gain an unfair advantage in sports performance.

If it is discovered athletes have been using PEDs, they may be tested, penalised, disqualified, lose their titles or records, and/or be banned from competitions. Normally two samples are taken from the athlete to improve the reliability of the testing (Figure 4.12.1).

Six examples of PEDs are anabolic steroids, human growth hormone, blood doping, erythropoietin, stimulants and diuretics.

Anabolic steroids

These are chemicals that mimic the effects of the male sex hormone testosterone. They are known to increase muscle size, strength and endurance, and are often used to improve performance in strength-based sports such as weightlifting (Figure 4.12.2), bodybuilding and sprinting.

Human growth hormone (HGH)

This is a hormone that is naturally produced by the body to regulate growth and cell reproduction. Synthetic HGH is an artificial version of this hormone used as a performance-enhancing drug to promote muscle growth, increase strength, and improve recovery, making it popular among athletes in various sports.

Blood doping

Blood doping increases the ability of blood to carry oxygen around the body to muscles. Blood doping can be done through methods such as blood transfusions or the use of blood-doping agents such as erythropoietin (EPO). Blood doping is banned in sports as it can provide an unfair advantage by enhancing endurance performance.

Erythropoietin (EPO)

This is a hormone that stimulates the production of red blood cells in the body. Synthetic EPO is used as a PED to increase the oxygen-carrying capacity of the blood, which can enhance endurance performance in sports such as cycling, long-distance running and cross-country skiing.

Stimulants

These drugs increase alertness, attention and energy levels, and can also decrease fatigue. Examples of stimulants used as PEDs are amphetamines, which can improve focus and endurance, and caffeine, which can increase alertness and reduce perception of effort during physical activity.

Diuretics

These drugs increase urine production and are often used to mask the presence of other banned substances in the body. Diuretics are sometimes used by athletes to quickly shed weight for sports that have weight-class categories, but they can also pose health risks and are banned in most sports.

It is important to note that the use of PEDs in sports is generally considered unethical and against the rules of most sporting organisations. They can pose serious health risks and provide an unfair advantage to those who use them, compromising the integrity of sports competitions.

SC 1 CHECK YOUR UNDERSTANDING

Discuss the reasons some athletes might resort to using performance-enhancing drugs to win, despite the risks and ethical concerns.

SC 2 I can explain how performance-enhancing drugs are detected in the body

When athletes take PEDs, these substances can leave traces or 'markers' in their body. These markers can be chemicals or substances that are not normally present in the body or are present in higher levels than usual. For example, anabolic steroids, which are a type of PED, can be detected in the body because they are synthetic substances that are not naturally produced by the body. Alternatively, the PEDs may cause the synthesis of other chemicals in the body. These are called **metabolites**, and if they are detected, this might be evidence that illegal drugs have been used.

KEY TERM

metabolite a substance made or used by the body when breaking down food, drugs or chemicals



FIGURE 4.12.3 A urine sample being analysed for evidence of drug use

KEY TERM

chromatography a method of separating a mixture by making it move over or through another stationary material



FIGURE 4.12.4 Mass spectrometry is able to detect the presence of certain molecules in a blood or urine sample.



FIGURE 4.12.5 An immunoassay analysis, using a lateral flow technique

To detect PEDs, athletes may be required to provide urine or blood samples. Hair and saliva can also be collected for analysis, but urine and blood samples are the most common (Figure 4.12.3). Samples are collected in a special container. Blood samples are taken using a needle and a small vial. These samples are then sent to a specialised laboratory for analysis.

In the laboratory, scientists use sophisticated equipment and methods to analyse the samples. They may use techniques such as **chromatography**, mass spectrometry and immunoassays to identify and measure the presence of PEDs or their markers in the samples. These methods are highly sensitive and accurate, and they can detect even very small amounts of PEDs in the body.

Mass spectrometry

Mass spectrometry works by measuring the mass of molecules and the fragmentation of the molecule (otherwise known as the molecule's fingerprint) and match the data with a database of hundreds of thousands of chemicals (Figure 4.12.4). Because the mass and fragmentation of molecules that are present in a range of drugs are known, the recorded masses can be used to identify which of these molecules are present in the sample.

Immunoassays

Immunoassays are techniques primarily used to detect synthetic human growth hormone (HGH). Immunoassays work by introducing antibodies into the body. Antibodies are chemicals that will combine with specific molecules, normally to protect the body from harmful substances. The new substances formed when the chemicals combine are often coloured (Figure 4.12.5). The immunoassay detects the colour, which provides evidence for the presence of molecules such as synthetic HGH.

Results of the analysis

Once the analysis of a test is complete, the results are reviewed by experts who interpret the findings. If the laboratory detects the presence of PEDs or their markers in the athlete's sample, it can be an indication that the athlete has used PEDs, which is against the rules of most sports organisations. If evidence for the use of a PED is found in the first sample, a second sample is tested to check the findings.

PED testing is a complex process that requires specialised knowledge and equipment, and it is conducted by trained professionals in accredited laboratories. The goal of PED testing is to ensure fair competition in sports and to maintain the integrity of the sport by preventing the use of illegal substances that can give athletes an unfair advantage.

Athletes who are found to have used PEDs may face serious consequences, such as disqualification, suspension and damage to their reputation. It is always best to compete in sports using your natural abilities and without resorting to any banned substances.

SC 2 CHECK YOUR UNDERSTANDING

List the two main types of samples that athletes must provide to test for PEDs.

SC 3 I can explain how rapid chemical tests are used to identify performance-enhancing drugs

Rapid chemical tests are used to quickly identify the presence of PEDs in a sample, such as urine or blood. These tests work by using chemical reactions to detect the specific PEDs or their metabolites in the sample. You may be familiar with the COVID-19 rapid (antigen) chemical tests. The PED rapid chemical tests work in a similar way.

Here is a simplified step-by-step explanation of how rapid chemical tests are used.

Sample collection

A urine or blood sample is collected from the athlete undergoing testing.

Test kit

A rapid chemical test kit is used, which contains specialised chemicals. These chemicals can react with specific PEDs or chemicals (called metabolites) that are produced by the PEDs.

Chemical reaction

The sample is mixed with the reagents in the test kit, and if PEDs or their metabolites are present, a chemical reaction takes place where chemicals combine together.

Results

The chemical reaction produces a visible change in colour or other observable change, which provides evidence for the presence of the PEDs or their metabolites in the sample.

Interpretation

The test results are interpreted using criteria provided by the test kit manufacturer or testing agency. If the test indicates the presence of PEDs, further testing may be conducted using more accurate and reliable methods to confirm the results.

Rapid chemical tests are designed to provide quick and preliminary results (e.g. Figure 4.12.6). Chromatography and mass spectrometry are more advanced techniques that may be required to confirm the results. These tests play a crucial role in detecting the use of PEDs in sports, ensuring fair competition.



FIGURE 4.12.6 A rapid test for Tramadol, showing a negative test result; this PED has been a banned substance for athletes since 2024.

SCIENCE IN SOCIETY

Detecting performance-enhancing drugs in Australia

In Australia, the fight against PEDs is a top priority for sports organisations and regulatory bodies. Rapid chemical tests have been developed to detect these substances in athletes' bodies, ensuring fairness and integrity in sports. However, some tests still require laboratory analysis. The Australian Sports Anti-Doping Authority (ASADA) plays a crucial role in implementing these testing methods. ASADA conducts regular testing of athletes, both in and out of competition, to ensure compliance with anti-doping regulations. The organisation also educates athletes about the risks and consequences of using PEDs, promoting a culture of clean and fair competition.

Unfortunately, some Australian athletes, intentionally or unintentionally take PEDs. Their reputation and career become forever tainted. One example is Shane Warne. Shane was one of the best spin bowlers for the Australian cricket team. He was banned from playing cricket for 12 months after testing positive to two banned diuretics in 2003. Diuretics are banned because they can mask other banned PEDs. Another Australian example is Stephen Dank. Stephen, a sports scientist, has a lifetime ban for injecting banned steroids and hormones into Essendon Football Club players.

To discover more, and see who is currently sanctioned from competing in their sport, visit the Sport Integrity Australia website.

SC 3 CHECK YOUR UNDERSTANDING

List the steps involved in using a rapid chemical test to detect PEDs in a urine sample.

Lesson review

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

1. Provide one example of a performance-enhancing drug.
2. Compare the use of performance-enhancing drugs with natural training methods in terms of effectiveness and risks.
3. Name the technique used to separate the components of urine to analyse on a mass spectrometer.
4. Explain why a second sample is required.
5. Compare how anabolic steroids and EPO (erythropoietin) affect the human body.
6. Explain how immunoassays work to detect performance-enhancing drugs.

4 Chemical change and energy

Topic summary

The key concepts included in this topic are:

- Substances can undergo both chemical and physical changes.
- Chemical indicators measure chemical and physical changes.
- Exothermic and endothermic reactions release or absorb heat as part of the reaction.
- Combustion reactions are a type of exothermic reaction that produce heat and light.
- Biodegradable materials can be substituted for traditional plastics.
- First Nations Australians used both physical and chemical reactions.
- Chemical reactions can be represented as word equations, chemical equations and 2D and 3D models.
- Chemical energy can be transformed into other forms of energy.
- Performance enhancing drugs are detected by collecting blood, urine, hair or saliva samples and analysing them using rapid chemical tests or laboratory tests.

Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

Remember

1 Describe what biodegradable materials are.

2 Identify the physical change involved in extracting pigment from red cabbage.

3 Define a performance-enhancing drug.

Understand

4 Explain the difference between a physical change and a chemical change.

5 Explain how you can determine if a reaction is exothermic.

6 Cycad seeds contain toxins that are removed by microbes in fermentation. Explain how the fermentation of cycad seeds by First Nations Australians is a chemical reaction.



Apply

7 Apply your understanding of energy transformations to describe how a battery works.

8 Design an experiment to test the effectiveness of different chemicals in a heat pack.

Analyse

9 Compare and contrast melting ice and burning wood in terms of physical and chemical changes.

10 Compare the combustion of wood and petrol in terms of energy output and environmental impact. Refer to Table 4.10.3 for chemical energy values.

11 You are comparing the energy content of different fuels and foods.

- **a** Name the equipment used for measuring the energy content of a fuel.
- **b** Describe how you would measure the energy content of a food item using the equipment named in your answer to part a.
- **c** Explain why the energy content of fuels is generally higher than that of foods.
- **d** Compare the practical uses of high-energy fuels with those of high-energy foods.

12 Draw the 2D model representation of the following chemical reaction:

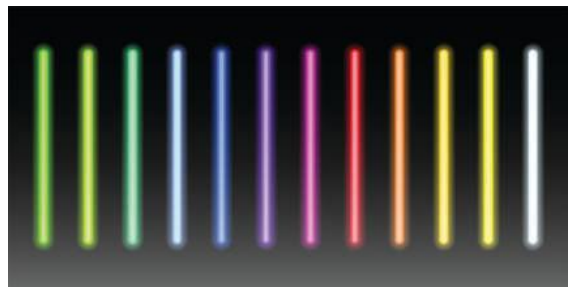
propane + oxygen → carbon dioxide + water

$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

Extension: Research task

13 Chemiluminescence is a type of reaction carried out by a non-living system that produces light. Glow sticks are a typical example of a chemiluminescence reaction. Many different colours can be created by changing the dye. Glow sticks contain two compartments, separated by a thin sheet of glass or plastic. Breaking this sheet allows the chemical reactants to mix together. The reaction takes place and the chemical energy is transformed to light energy. Once the chemical reaction has finished, no more light is produced. Fireworks are another example of a chemiluminescent reaction.

Research the ingredients in fireworks or glow sticks that produce the coloured light. Investigate the safety of these ingredients, where they are sourced and their impact on the environment when the glow sticks are disposed of. Explore which chemicals and their colours are safest for humans and the environment.



Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any particular areas that you are confident in, and others where you are not so sure.

4 Glossary

acid a chemical that, when dissolved in water, is corrosive, can react with reactive metals to form hydrogen gas and has a pH of less than 7; foods that are acidic have a sour taste

alkali a chemical that, when dissolved in water, can react with organic tissue and has a pH of more than 7; foods that are alkaline have a bitter taste

biodegradable can break down naturally in the environment without causing harm or leaving behind toxic residues

calcination heating of a solid chemical so that it can decompose into different materials

chemical bond a force of attraction that joins atoms together

chemical change a change that results in a new substance being formed

chemical reaction the process of rearranging atoms in substances to form different substances

chromatography a method of separating a mixture by making it move over or through another stationary material

combustion a chemical reaction in which a substance burns in oxygen gas to produce light and heat

compound a pure substance that is made up of two or more different types of atom chemically joined

element a substance made up of only one type of atom

endothermic reaction a chemical reaction that absorbs energy, often causing a temperature decrease in the surroundings

energy transformation the transformation of one form of energy into another form of energy

exothermic reaction a chemical reaction that releases energy, often causing a temperature increase in the surroundings

metabolite a substance made or used by the body when breaking down food, drugs or chemicals

microbe a living organism, such as a bacterium or virus, that is too small to be seen by the naked eye; also called a microorganism

molecule a group of atoms joined together with chemical bonds

nanotechnology using particles less than 100 nm (nanometres, or one-billionth of a metre) for technological improvements in science and engineering

neutral neither acidic nor alkaline

physical change a change that does not result in a new substance being produced

potential energy energy stored by an object (because of its position or chemical structure) that can be transformed into another form of energy

precipitate a solid formed during a chemical reaction

product a substance produced by a chemical reaction

pyrolysis substance is heated intensely but without air (or oxygen) present

reactant substance that takes part in a chemical reaction

reduction reaction a different type of chemical reaction that usually converts ore into metal

sustainability the conservation of resources in order to maintain a balance in a system, such as an ecosystem

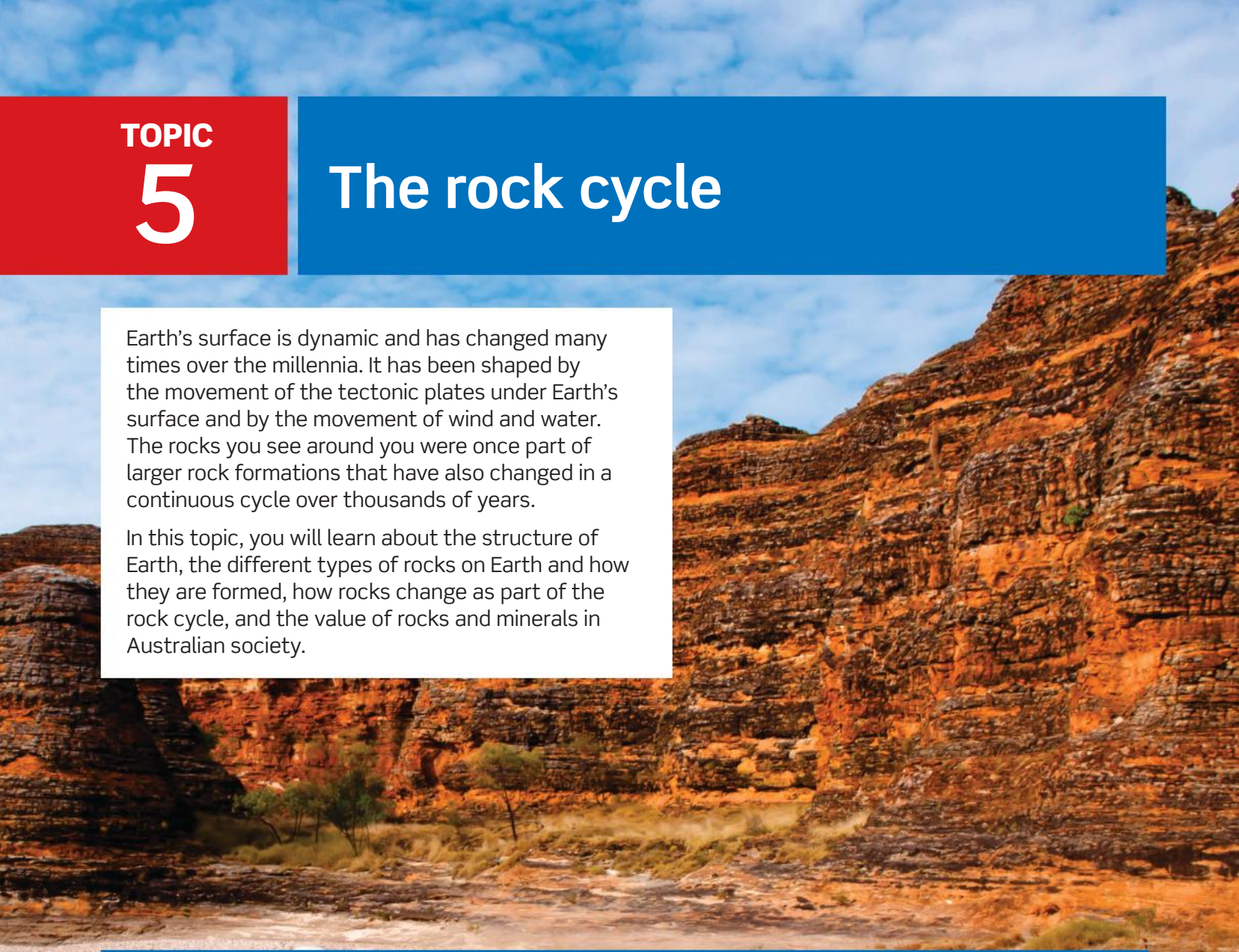
synthesis reaction a chemical reaction in which a compound is produced by the combination of elements

system a collection of interconnected components



TOPIC 5

The rock cycle



Earth's surface is dynamic and has changed many times over the millennia. It has been shaped by the movement of the tectonic plates under Earth's surface and by the movement of wind and water. The rocks you see around you were once part of larger rock formations that have also changed in a continuous cycle over thousands of years.

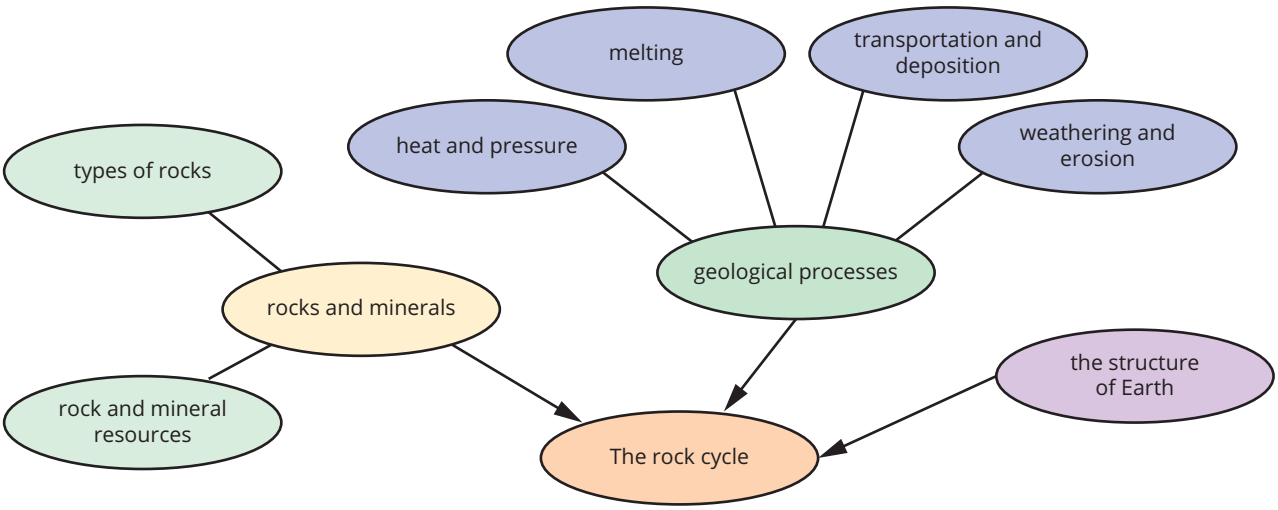
In this topic, you will learn about the structure of Earth, the different types of rocks on Earth and how they are formed, how rocks change as part of the rock cycle, and the value of rocks and minerals in Australian society.

Learning intentions

- ☐ To understand the internal structure of Earth **215**
- ☐ To understand how rocks on the surface of Earth can change **219**
- ☐ To be able to investigate physical and chemical weathering **223**
- ☐ To understand the formation of sedimentary rocks **225**
- ☐ To be able to investigate how advances in deep Earth imaging have enabled identification of resources in sedimentary rock **232**
- ☐ To understand the formation of igneous rocks **234**
- ☐ To understand the formation of metamorphic rocks **238**
- ☐ To be able to investigate the source of metamorphic rocks **244**
- ☐ To understand how environmental changes affect the rock cycle **248**
- ☐ To be able to explain how the mining of Australian mineral resources influences/ impacts society **254**
- ☐ To be able to model, describe and analyse economic and environmental impacts of mining in Australia **257**
- ☐ To understand how sustainability priorities have led to innovative practices in mining **259**

5 The rock cycle

The key concepts that you will use in this topic:



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

Structure of Earth

1 List Earth's four main layers.

2 Describe how temperature and pressure change from Earth's surface to Earth's centre.

Geological processes

3 Compare the processes of weathering and erosion.

4 Describe three types of weathering.

5 How do intrusive igneous rocks differ from extrusive igneous rocks?

Rocks and minerals

6 There are three types of rocks. What type is formed by:

- **a** melting and solidification of magma and lava?
- **b** deposition, compaction and cementation of eroded material?
- **c** high heat and/or high pressure conditions?

7 Name five rock and mineral resources that humans extract from Earth.

5.1 Structure of Earth

Lesson overview

Earth is not a solid uniform mass. Instead, it is made up of different layers that have different properties. In this lesson, you will learn about Earth's structure and its layers and how heat energy is distributed throughout Earth.

SC 1 I can identify the different layers of Earth

Earth consists of four main sections: the crust, the mantle, and the outer and inner core. Figure 5.1.1 shows how these layers are arranged.

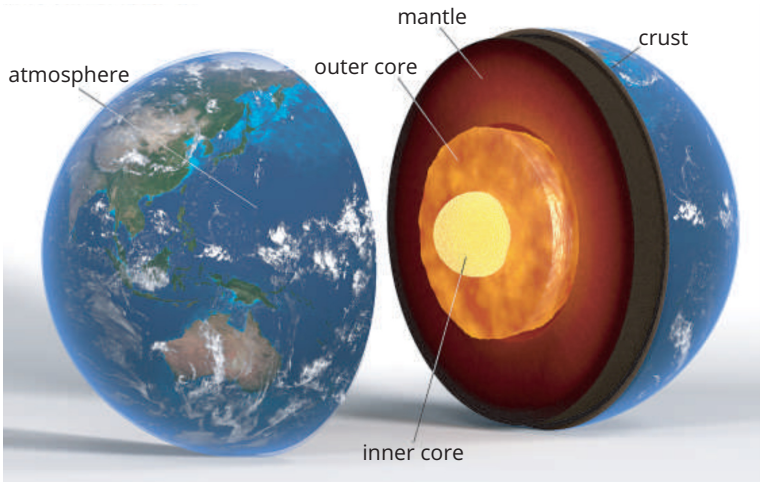


FIGURE 5.1.1 The four layers of Earth

Earth was formed approximately 4.5 billion years ago. Over time, the internal structure of Earth became made up of a solid inner core, a liquid outer core, a solid but fluid hot mantle, and a solid rock crust. The liquid outer core is responsible for Earth's magnetic field.

Scientists know about the composition of Earth's internal layers because of the behaviour of earthquake waves (P-waves and S-waves) as they travel through Earth. P-waves travel at different speeds through solids and liquids. S-waves are not able to travel through liquids at all (Figure 5.1.2).

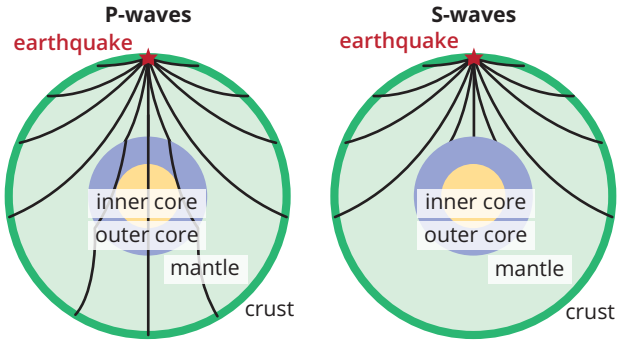


FIGURE 5.1.2 Earthquake P-wave and S-wave paths through Earth

Learning intention

To understand the internal structure of Earth

Success criteria

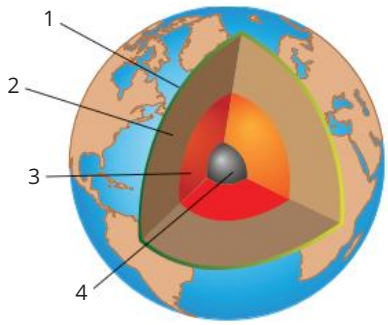
SC 1: I can identify the different layers of Earth.

SC 2: I can describe the layers of Earth's internal structure.

SC 3: I can describe the distribution of heat energy within the internal structure of Earth.

SC 1 CHECK YOUR UNDERSTANDING

Refer to the diagram below showing the internal structure of Earth.



a Identify each of Earth's layers (numbered 1 to 4).

b For the two innermost layers, state whether they are solid or liquid.

SC 2 I can describe the layers of Earth's internal structure

Each layer of Earth is different.

KEY TERMS

crust the outermost layer of Earth, composed of solid rock

mantle the solid layer of Earth between the crust and the outer core

Crust

The outermost layer of Earth is the **crust** (Figure 5.1.3). The crust is solid and very thin compared to the other layers. Its thickness varies from 7 kilometres beneath the oceans, to 30 or more kilometres beneath the continents. It is composed mostly of oxygen, silica and aluminium.

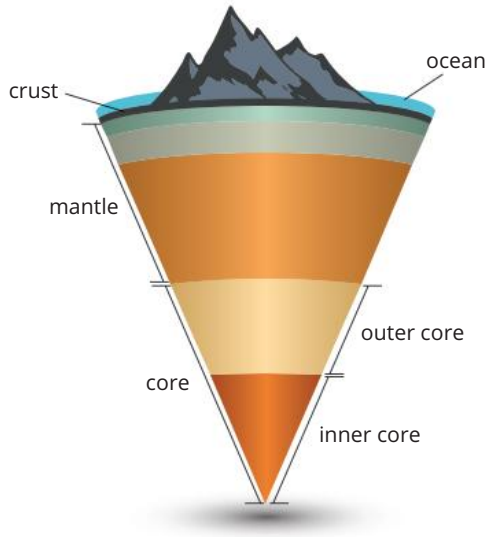


FIGURE 5.1.3 The structure of Earth showing the crust, mantle, inner core and outer core

Mantle

The **mantle** is the layer underneath the crust. It is much hotter than the crust, and the composition of this layer changes as it gets deeper. The mantle consists mainly of oxygen, silica and magnesium.

The uppermost solid layer of the mantle combines with the crust to create Earth's rigid outer shell called the **lithosphere** (Figure 5.1.4).

The **asthenosphere** is near the top of the mantle (Figure 5.1.4), just below the solid lithosphere, and it contains **rock** that can move very slowly. This rock is described as behaving plastically because it can bend or change shape under pressure, like plasticine, without breaking.

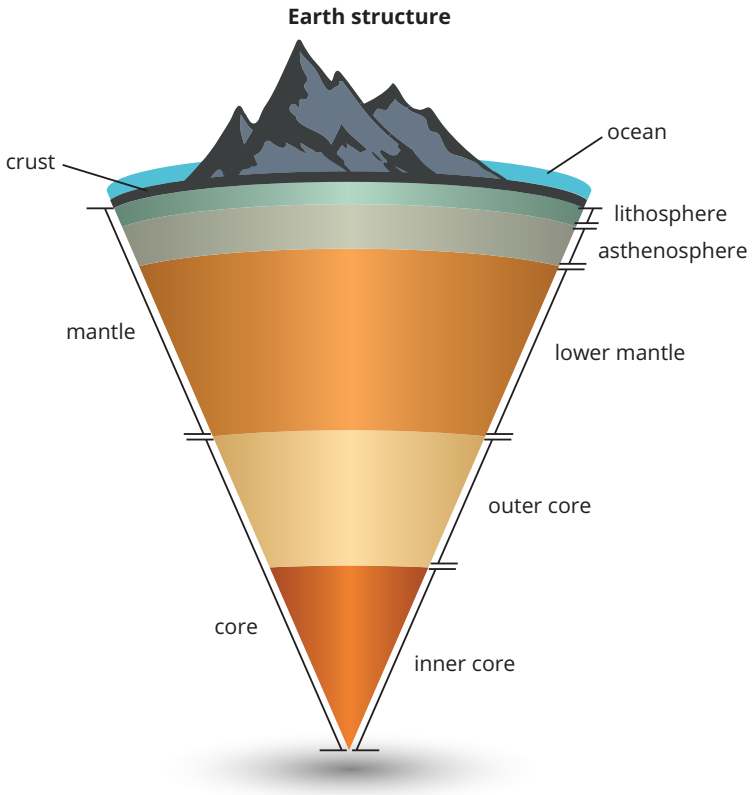


FIGURE 5.1.4 The mantle is divided into the lithosphere, asthenosphere and lower mantle.

However, in the deepest part of the mantle (the lower mantle) the rock flow is also slow, but these rocks are rigid and break under pressure (Figure 5.1.4).

Outer core

The **outer core** is liquid (Figure 5.1.4). It is thought to consist of iron and nickel.

Inner core

The **inner core** of Earth (Figure 5.1.4) is also thought to consist of iron and nickel. It is so dense and the pressure so great inside the inner core that the iron and nickel do not melt.

SC 2 CHECK YOUR UNDERSTANDING

How does Earth's outer core differ from the:

a inner core?

b mantle?

KEY TERMS

lithosphere the crust and the upper mantle together; Earth's tectonic plates

asthenosphere the layer of Earth near the top of the mantle, just below the solid lithosphere, and containing rock that can move very slowly

rock a solid mass of one or more minerals

Scifile

Earth's deepest hole

The deepest hole ever drilled by humans is the Kola Superdeep Borehole in Russia. It is about 12 kilometres deep—that's not even halfway through Earth's crust! The attempt to reach the mantle had to stop after 20 years when the temperature in the crust reached 180°C—far too hot for the drilling equipment.

KEY TERMS

outer core a liquid layer of Earth's interior, primarily composed of liquid iron and nickel; located beneath the solid mantle and surrounds the inner core

inner core extremely hot, solid ball made of iron and nickel at the very centre of Earth

SC 3 I can describe the distribution of heat energy within the internal structure of Earth

KEY TERMS

primordial something that originated during the planet's formation process a very long time ago

geothermal energy the heat energy that comes from within Earth

The inner core of Earth is very hot with a temperature ranging from 5000°C to more than 6000°C (Figure 5.1.5). The heat is generated from radioactive decay and **primordial** heat from when Earth was formed. The solid core is so dense, and the pressure inside the core so great, that it does not melt.

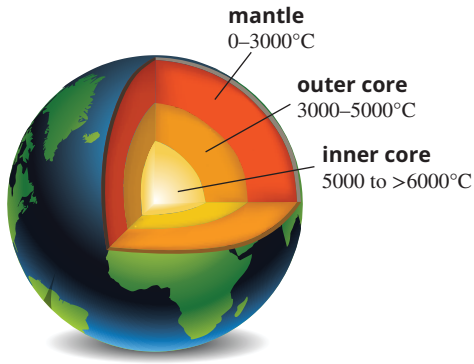


FIGURE 5.1.5 Estimated temperatures within Earth's three interior layers

The outer core is liquid, and it is the movement of this liquid that helps distribute heat to the mantle and Earth's crust. Heat flows from warmer objects to cooler objects, so the heat from the warmer core is transferred to the cooler mantle and crust.

Heat energy that is generated within Earth is known as **geothermal energy**. It is geothermal energy that produces hot springs and geysers at Earth's surface (see Figure 5.1.6).



FIGURE 5.1.6 Geothermal energy produces hot springs and geysers at the surface near volcanoes at El Tatio in Chile.

SC 3 CHECK YOUR UNDERSTANDING

Why does heat makes its way from the inner core to the mantle and crust?

Lesson review

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

1 Explain the location of Earth's mantle in relation to the other layers.

2 Describe how the behaviour of different types of earthquake waves has allowed scientists to determine Earth's internal structure.

3 If scientists discovered a new layer between the lower mantle and the outer core, what properties might you expect this layer to have?

4 Identify the layers of Earth that have the following characteristics.

- a generates Earth's magnetic field
- b contains the asthenosphere
- c has the main elements of nickel and iron in a solid state
- d does not allow the passage of earthquake S-waves
- e composed of solid rock with thickness ranging from 7 to 50 kilometres
- f contains material at the hottest temperature and highest pressure
- g consists mostly of oxygen, silica and aluminium
- h contributes to the rigid outer shell of Earth known as the lithosphere

5 Outline two sources of heat within Earth's internal structure.

6 Explain why geysers and hot springs are found near volcanoes.

5.2 Changes to rocks on the surface of Earth

Lesson overview

When you look at a rock, you may not consider that the rock was originally part of a larger rock. The rocks you see in your garden, in parks and at the beach were once part of a larger rock mass (Figure 5.2.1). These larger rock masses have changed over time, affecting their appearance and creating smaller rocks. In this lesson, you will learn how and why rocks change and how this affects the landscape.

SC 1 I can describe different types of weathering

Weathering causes rocks to change and break down. There are three main categories of weathering.

Physical weathering

Physical weathering (sometimes referred to as mechanical weathering) breaks rock into smaller pieces without changing its chemical composition. Physical weathering can happen in four ways.

- Wind can carry fine particles of rock, which cause wear to the surface of other rocks as they blow past.
- If rocks expand and contract quickly due to a change in temperature, they may crack.
- Water entering rocks and expanding when it freezes can cause rocks to crack and break.
- When salt water evaporates, salts form crystals inside rocks. This process is called **crystallisation**. The crystals apply a force on the rocks, which causes fractures and bits of rock to fall off.

Often, more than one of these processes can occur at the same time, contributing to the formation of unique landscape features, such as the fairy chimneys shown in Figure 5.2.2.



FIGURE 5.2.2 These fairy chimneys, a unique landscape feature in Cappadocia (Türkiye), have been created through a combination of physical weathering processes.

Learning intention

To understand how rocks on the surface of Earth can change

Success criteria

SC 1: I can describe different types of weathering.

SC 2: I can describe, with examples from Australia, the difference between weathering and erosion.

SC 3: I can explain, with examples from Australia, the process of deposition and the land formations produced as a result.



FIGURE 5.2.1 Rocks on Currumbin Beach in Queensland

KEY TERMS

weathering the physical, chemical and biological processes that break down rocks into smaller pieces

crystallisation evaporation of a solvent from a solution, leaving solute behind as crystals



FIGURE 5.2.3 The red colour of these rocks at Uluru is due to the presence of iron.



FIGURE 5.2.4 These tree roots have pushed through cracks in the rocks and caused the rock to split.

KEY TERM

erosion the movement of weathered rock particles from the site of the weathering



FIGURE 5.2.5 London Bridge, a natural arch limestone formation in coastal Victoria, has been formed by chemical weathering and erosion.



FIGURE 5.2.6 Karlu Karlu (Devils Marbles) have formed as a result of rapid temperature changes (physical weathering) and erosion.

Chemical weathering

Chemical weathering occurs when water dissolves chemicals from the surrounding soil and air. These chemicals may then react with a rock, causing it to crack or change.

Air contains oxygen and carbon dioxide. When these gases are dissolved in water, they can react with minerals in nearby rocks. These reactions may cause the rock to crumble or change colour on the surface.

Uluru is a well-known example of the process of chemical weathering. The original rock of Uluru is grey and called arkose. Water from the rain and oxygen in the air react with the iron in the rock to produce oxides of iron, which give Uluru its famous red colour (Figure 5.2.3).

Biological weathering

Biological weathering is caused by moss, lichens, algae, and plant or tree roots forcing themselves through small cracks in rocks to create larger cracks (Figure 5.2.4). Biological weathering can even split the rock. Some plant roots can travel through rocks by releasing acids or an enzyme (a protein which speeds up chemical reactions) that softens the surrounding rocks.

SC 1 CHECK YOUR UNDERSTANDING

Compare physical and chemical weathering in terms of their processes.

SC 2 I can describe, with examples from Australia, the difference between weathering and erosion

Weathering weakens rocks and creates small rock particles, but **erosion** moves these particles elsewhere by the action or movement of gravity, ice, water or wind.

London Bridge, Victoria

The limestone rock formation known as London Bridge (Figure 5.2.5) is near the Great Ocean Road in south-west Victoria. It was originally connected to the mainland until the inner span collapsed in 1990. When it rains, limestone slowly dissolves due to a chemical reaction with the rainwater in a process of chemical weathering. The limestone is further weakened by physical weathering (action of wind and salt crystallisation). The movement of wind and water against rock, and gravity, causes small pieces of the rock to erode. Over time, this process creates natural arches or bridges, which can eventually collapse due to weathering.

Karlu Karlu (Devils Marbles), Northern Territory

Karlu Karlu (or Devils Marbles) (Figure 5.2.6) are giant granite boulders in the Northern Territory. They were formed by molten rock that became solid when it cooled underneath a layer of sandstone. Once this rock solidified, vertical and horizontal cracks appeared due to physical weathering, forming rectangular blocks. These blocks have since become rounded due to further rapid temperature changes. The 'marbles' appear to be stacked on top of each other as the sandstone surrounding the granite has been eroded.

Tessellated Pavement, Tasmania

Tessellated Pavement in the Tasman Peninsula (Figure 5.2.7) is made of siltstone that was formed over 300 million years. The rocks fractured due to the movement of Earth. Over time, physical weathering from the crystallisation of salts inside the rock, and erosion by water (waves), have caused the pattern to deepen to form pans, contributing to its unique appearance.



FIGURE 5.2.7 Tessellated Pavement in Tasmania is a result of physical weathering (crystallisation) and water erosion.

SC 2 CHECK YOUR UNDERSTANDING

Explain how weathering and erosion are different.

SC 3 I can explain, with examples from Australia, the process of deposition and the land formations produced as a result

Erosion causes particles of rock to move to different places, and this movement ends when these particles are **deposited** and settle in an area. The particles settle in layers of materials called **sediments**. When the water, wind or ice that is transporting the particles of rock slows down, deposition occurs.

Examples of depositional landforms include coastal landforms such as beaches, deltas and sand dunes.

KEY TERMS

deposited the settling of broken rock material to form sediment
sediment solid material that has broken down and moved because of erosion
spit a stretch of beach material, connected to land and jutting out into the water

Scifile

Fossil formation

Sediments that form sedimentary rocks often contain fossils. When plants and animals die, they can get buried by sediments. Eventually, over millions of years, parts such as teeth, bones and leaves turn into body fossils. Trace fossils are those that are made by an organism or left behind, such as scat or footprints.

Sand dunes

Sand dunes are formed as wind transports and then deposits individual grains of sand. Some grains are trapped by plants or are deposited in areas sheltered from the wind. As more and more sand accumulates, sand dunes are formed. Near beaches, the dunes are held together by plants so they are fairly stable. In desert areas, the dunes are constantly moving and changing (Figure 5.2.8).



FIGURE 5.2.8 Wind transports and deposits sand grains on Nappanerica (Big Red) on the edge of the Simpson Desert.

Spits

A **spit** is a depositional landform that forms along coastlines. Spits form when waves lose energy so that the material they carry (usually beach sand) is deposited. The deposited sediment builds up over time to form a long ridge connected to land at one end and jutting out into a water body (sea, ocean, river mouth) at the other.

Double Island Point in the Cooloola Region of Queensland is a rocky island connected to the mainland by the sand dunes of Teewah and Rainbow Beaches. On the northern side of Double Island Point is an extensive spit (Figure 5.2.9). The shape and size of the spit constantly changes depending on tides and ocean conditions. Large seas generated by cyclones can cause the spit to disappear entirely.



FIGURE 5.2.9 The sand spit at Double Island Point with the extensive sand dune system of Rainbow Beach in the background

Rivers

Rivers are shaped by both erosion and deposition. The Murray River meanders (follows a winding course) because it travels slowly across a plain (Figure 5.2.10). Sand and other sediments are deposited on the inside of its bends because that is where the river travels the slowest. On the outside of the bends, erosion can still occur as the water flows more rapidly.

Fast-flowing rivers can carry larger sediments, whereas slow-moving rivers can only carry smaller sediments. When the river stops flowing or water is very shallow, even the tiniest sediments settle on the riverbed and may form bars.

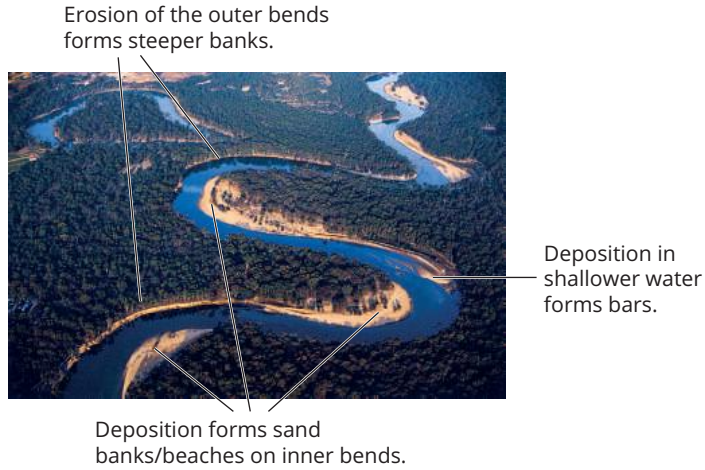


FIGURE 5.2.10 Depositional and erosional features formed in the meanders of the Murray River

SC 3 CHECK YOUR UNDERSTANDING

Describe how deposition occurs after erosion.

Lesson review

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

1. What are the three main types of weathering?
2. Compare physical and biological weathering in terms of their processes and effects on rocks.
3. In the desert regions of Australia, how might weathering and erosion work together to shape the landscape?
4. The Twelve Apostles are a famous limestone rock formation of sea stacks off the coast of Victoria. At the beginning of the 21st century, there were nine. Two have since collapsed.
   a. Describe the role of weathering in the formation of the Twelve Apostles. Consider the type(s) of weathering that has occurred.
   b. Explain how erosion has contributed to their current shape. Consider the main agents of erosion.
   c. Evaluate the long-term impacts of these processes on the remaining sea stacks.
5. Create a diagram to identify where one depositional feature and one erosional feature are likely to occur in the meanders of the Murray River.
6. Determine if erosion or deposition is the main factor contributing to the formation of each of the following landscape features.
   a. Fingal Spit off Fingal Beach in New South Wales
   b. Karlu Karlu (Devils Marbles) in Northern Territory
   c. Big Red sand dune in western Queensland
   d. Cottesloe Beach in Western Australia
   e. Tessellated Pavement in Tasmania
   f. London Bridge in Victoria
   g. Bunda Cliffs in South Australia

5.3 Weathering of rocks

Introduction

Weathering is the process of rocks breaking down into smaller pieces. Weathering can occur because of physical, chemical and biological processes.

The rocks in Kalbarri Gorge in Western Australia (Figure 5.3.1) have been broken into smaller rocks over thousands of years.

In this practical investigation, you will investigate how chemicals and changes in temperature can cause the weathering of rocks.

Background

Two types of weathering involve chemical or physical processes. Chemical reactions involve the creation of new substances. Physical processes involve changing the form of a substance and are easier to reverse than chemical processes.

Aim

To investigate how ice and chemicals cause weathering

Materials

- vinegar
- 2 small samples each of granite, limestone and sandstone (to fit in test tubes)
- 6 test tubes and a test-tube rack
- plaster of Paris
- 2 margarine containers or milk cartons
- small water balloon
- spoon or spatula
- rubber gloves

Assessment of risk

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

Method

Part A: The effect of acid and water

1. Label your test tubes 1 to 6 (Figure 5.3.2 on the following page).
2. Put small samples of granite into test tubes 1 and 2, limestone in test tubes 3 and 4, and sandstone in test tubes 5 and 6 as shown in the diagram.
3. Add water to test tubes 1, 3 and 5.
4. Add vinegar to test tubes 2, 4 and 6.

Learning intention

To be able to investigate physical and chemical weathering

Success criteria

SC 1: I can conduct a safe experiment to model and compare the weathering of rocks.

SC 2: I can use knowledge of weathering to explain observations.

SC 3: I can analyse the effectiveness of an experiment as a representation of the weathering of rocks in the environment.



FIGURE 5.3.1 Weathering and erosion have created Nature's Window in the Inland River Gorges section of Kalbarri National Park.

SAFETY NOTES

- Do not mix plaster with your bare hands; mix with a spoon or spatula or use rubber gloves.
- Wear laboratory safety glasses and a dust mask when using dry plaster of Paris.

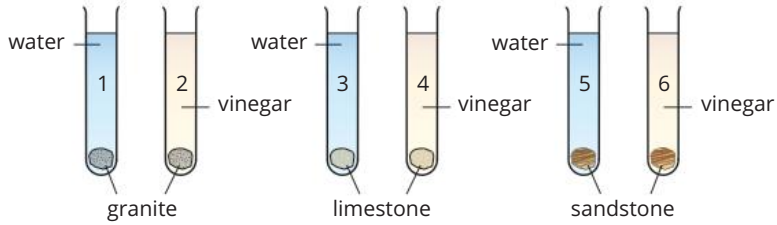


FIGURE 5.3.2 The set-up of test tubes to investigate the effect of acid and water on three rock types

5 Leave the test tubes in the test-tube rack and record any observations. Leave them set up overnight or until your next science class.

Part B: The effect of temperature

6 Mix up enough plaster with water to half-fill two margarine containers or cut-down milk cartons.

7 Fill a small balloon with water and tie it. Push the balloon into the plaster in one container and keep it below the surface so that it remains in the plaster after the plaster sets.

8 At the end of class, put both the margarine containers, or the cut-down milk cartons, in the freezer.

Results

Copy the results tables below into your notebook and record your observations.

Part A

Test tube	Rock	Liquid	Observations
1	granite	water	
2	granite	vinegar	
3	limestone	water	
4	limestone	vinegar	
5	sandstone	water	
6	sandstone	vinegar	

Part B

Container	Observations
1 (without water balloon)	
2 (with water balloon)	

Conclusion

1 Use the observations in Part A to explain the weathering of rocks by chemicals.

2 Use the observations in Part B to explain a possible effect of low temperatures on rocks.

Evaluation

Evaluate how well this experiment models the weathering of rocks in the environment.

5.4 Sedimentary rocks

Lesson overview

Sedimentary rocks are rocks made from sediments (Figure 5.4.1). Sediments are small particles of weathered rock or crystals that have been deposited and left behind by ice, water and wind. In this lesson, you will learn how sedimentary rocks are formed, the observable features of sedimentary rocks, and how fossils preserved in sedimentary rocks can be used to predict how and when a rock was formed.

SC 1 I can describe how and where sedimentary rocks are formed

Sedimentary rocks

Sedimentary rocks are formed at the bottom of large bodies of water, including oceans and large lakes. Some also form in deserts and caves.

Sediments are small fragments of rocks that pile up over time. The laying down of these rock fragments is called deposition.

As sediments layer on top of one another, they push down on the underlying sediments. This squeezes out excess water, and a compact denser structure forms. This process is known as **compaction**.

Naturally occurring minerals in water, such as silica and lime, can bind or cement the sediments together and create a more solid rock structure in a process called **cementation**.

Sediments that have undergone compaction and cementation form **sedimentary rocks** (Figure 5.4.2).

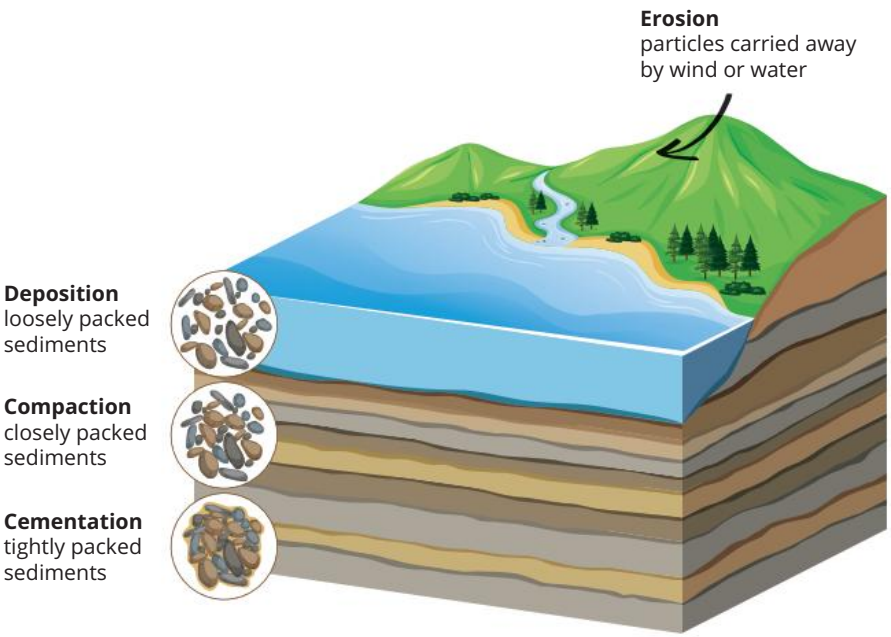


FIGURE 5.4.2 The three main stages of the formation of sedimentary rock

Learning intention

To understand the formation of sedimentary rocks

Success criteria

SC 1: I can describe how and where sedimentary rocks are formed.

SC 2: I can describe observable features of sedimentary rocks.

SC 3: I can explain how fossil evidence can be used to predict how and when a rock was formed.



FIGURE 5.4.1 Sediment has been deposited in layers to form sedimentary rocks.

KEY TERMS

compaction the squeezing of layers of sediments caused by pressure from layers above

cementation the binding together of sediments as part of the formation of sedimentary rock

sedimentary rock rock made by sediments being compacted and cemented together



FIGURE 5.4.3 This conglomerate is an example of a clastic sedimentary rock.



FIGURE 5.4.4 Stalactites form when water containing dissolved calcium carbonate evaporates, leaving behind a limestone precipitate.

Scifile

Ancient oceans

Many sedimentary rocks were formed in ancient oceans. The sediments that settled on the ocean floor millions of years ago underwent compaction and cementation to form rocks like limestone and shale. Many of these rocks also contain marine fossils such as turtles and trilobites that are now appearing in unexpected places like the Sahara Desert.



There are three types of sedimentary rocks.

Clastic

Clastic sedimentary rocks are formed from other rocks that have broken down through weathering and have then been compacted and cemented. Examples of clastic sedimentary rocks are conglomerate (Figure 5.4.3), mudstone, breccia and sandstone.

Chemical

Chemical sedimentary rocks can be formed in two ways:

- when minerals that are dissolved in water crystallise within sediments
- when water evaporates, leaving behind a build-up of sediment that forms a mass (Figure 5.4.4).

Examples of chemical sedimentary rocks are gypsum, halite and limestone.

Biogenic

Biogenic sedimentary rocks are formed by the compaction and cementation of dead plant or animal matter. Although most of these sediments come from organisms, some sediment might come from weathered rock. Figure 5.4.5 shows the formation process of coal, a biogenic sedimentary rock.

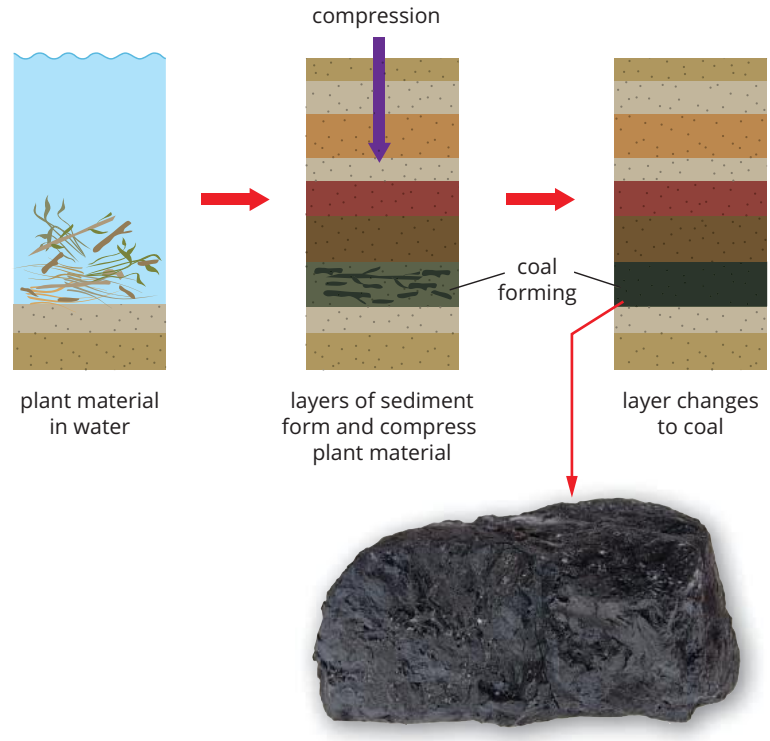


FIGURE 5.4.5 Coal is a biogenic sedimentary rock that formed over millions of years.

SC 1 CHECK YOUR UNDERSTANDING

Outline the three main stages of the formation of sedimentary rock.

SC 2 I can describe observable features of sedimentary rocks

Sedimentary rocks have observable features that will help you distinguish them from other types of rocks. There are three types of sedimentary rocks: clastic, chemical and biogenic. These types are classified based on how they are formed. Although they are formed in different ways, it is often difficult to distinguish between these three types of sedimentary rocks based solely on their appearance.

Clastic sedimentary rocks

Clastic sedimentary rocks have a range of properties, but not all clastic rocks share all these properties. Many have the following characteristics.

- They are made of fragmented pieces of rocks, known as clasts.
- They may be formed in layers.
- The grains in clastic sedimentary rocks do not interlock as they are cemented together.
- They may contain **fossils** (the preserved remains of animals).

KEY TERM
fossil the preserved remains of a once-living organism

Clastic sedimentary rocks, such as those in Figure 5.4.6, are classified in terms of grain size and shape.



conglomerate
large rounded rocks cemented between grains that are often microscopic



shale/mudstone
particles often microscopic, very soft rock



breccia
similar to conglomerate but lumps are sharp-edged



sandstone
particles of sand, usually harder than mudstone

FIGURE 5.4.6 Clastic sedimentary rocks are made of clasts cemented together and may contain fossils.

Chemical sedimentary rocks

Chemical sedimentary rocks have the following characteristics.

- They do not often have interlocking crystals, so they are easier to break.
- They are soft compared to igneous rocks, which are formed from the solidification of molten rock.
- Some are formed in salt water and may have a salty taste.

Four examples of chemical sedimentary rocks are shown in Figure 5.4.7.



chalk (a form of limestone)

desert rose

gypsum

halite (rock salt)

FIGURE 5.4.7 Four examples of chemical sedimentary rocks

Biogenic sedimentary rocks

Biogenic sedimentary rocks have the following characteristics.

- They are generally soft; although some (e.g. chert and flint) are quite hard.
- They are formed in layers.
- They may contain fossils.



FIGURE 5.4.8 Fossils can be clearly seen in this limestone formed as a biogenic sedimentary rock.

Limestone is normally formed as a biogenic sedimentary rock. It contains at least 50% calcium carbonate (commonly known as chalk) so its chalky appearance will help you to identify it. The original source of the calcium is the remains of corals and shells. Biogenic limestone may contain fossils (Figure 5.4.8). Note that a small amount of limestone on Earth is produced directly from calcium carbonate in water. Limestone formed in this way is classified as chemical sedimentary rock.

SC 2 CHECK YOUR UNDERSTANDING

In which two sedimentary rock types can fossils be found?

SC 3 I can explain how fossil evidence can be used to predict how and when a rock was formed

If the remains of an organism after it dies are quickly covered by sediment, then it may be preserved and become a fossil.

Fossils are often found where an organism's remains are located in sediments in water bodies such as in an ocean, lake or river (Figure 5.4.9). This means there is no oxygen in the sediment so there is little or no decomposition.

Organisms that die on land can also become fossilised when wind blows sediment to cover the remains.

The fleshy parts of the organism gradually decompose. The hard remains of the organism, such as bones, are replaced by minerals and so turn into rock, becoming fossilised. Over time, sediments continue to build up, compacting and cementing, and become sedimentary rock (Figure 5.4.10).



FIGURE 5.4.9 An organism's remains become buried in sediments in a water body.

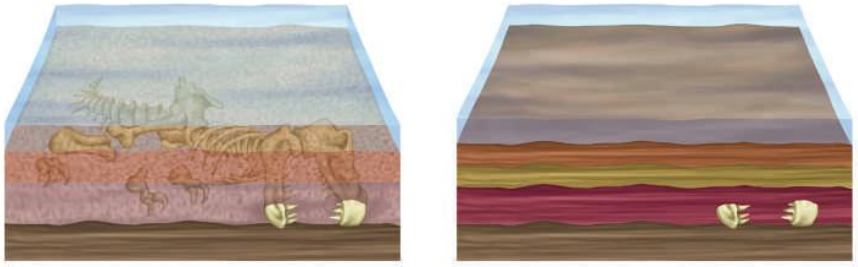


FIGURE 5.4.10 Hard remains of the organism are replaced by minerals and become compacted in the surrounding sedimentary rock.

Changes to Earth's surface such as movements in Earth's crust, weathering and erosion can expose the fossil at Earth's surface (Figure 5.4.11).

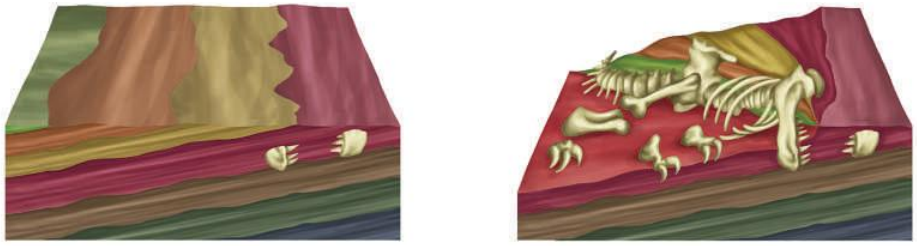


FIGURE 5.4.11 Fossilised remains of an organism become exposed at Earth's surface.

Index fossils

As layers of sedimentary rock are built up over time, deeper layers will generally be older than those closer to the surface. It is possible to compare the relative ages of rocks from different places using **index fossils**. A fossil must meet the following requirements to be an index fossil.

- It must have been found across a large area such as on different continents.
- The organism must have lived within a short period of time.
- The organism must also have been a part of a large population; that is, there were many of that organism living at the time.

Index fossils within layers can mark where layers were formed around the same time but at different locations. Index fossils can be used to check the order of the layers and to check the age of the rock strata that housed the fossils.

KEY TERM

index fossil a fossil that can be used to compare the relative age of rock strata in different locations

SCIENCE IN SOCIETY

Morocco's fossil trade

Morocco contains some of the world's richest fossil sites. Fossils date from the pre-Cambrian to recent geological time. Millions of years ago, the Sahara Desert in Morocco would have been a shallow sea. Prehistoric marine organisms such as ammonites, trilobites, orthocones and sharks lived in these waters in great numbers. When they died, their bodies were buried in the sediments on the sea floor, and over millions of years were turned into stone. Dinosaur teeth, mainly from the river-dwelling theropod dinosaur *Spinosaurus* are also abundant. The arid environment of Morocco has made it easy to find fossils on the surface. Other large finds are in marble quarries.



FIGURE 5.4.12 A roadside stall selling fossils in Morocco

The rich abundance of fossils in Morocco has created a dilemma for Moroccans and palaeontologists (scientists who study fossils). For many Moroccans, the fossils provide their only source of income. Thousands of Amazigh, the ethnic peoples of Morocco, excavate by hand to collect fossils to sell. Small roadside stalls sell specimens directly to tourists. Larger scale operations create furniture and other pieces from the fossils. However, there are scientific concerns that excavations by non-scientists may damage important specimens.

The Moroccan fossil trade's focus is commercial, so specimens may be discarded that are not seen as valuable. These ignored specimens could be very significant to palaeontologists. With a ready market selling fossils to collectors worldwide, rare specimens may disappear into private collections and so would not be available for scientific study.



FIGURE 5.4.13 A coffee table created from a slab of black marble with ammonite and orthocones fossils

Despite these scientific concerns, Morocco's fossil trade has allowed palaeontologists to make some very significant scientific discoveries. Many new species from the past have been discovered. Hundreds of trilobite species from 570 to 245 million years ago, many not found elsewhere in the world, have been found in Morocco. The methods of retrieving the fossils are, in so many cases, not conducted according to palaeontology protocols. Yet, without the fossil trade, many new fossil species would never have been uncovered. The science community's knowledge of the geological record has greatly improved because of the fossils that have been unearthed. In the future, conservation of the fossil sites and more sustainable management approaches to the trade should see further growth in scientific knowledge.

SC 3 CHECK YOUR UNDERSTANDING

Explain how fossils are preserved in sedimentary rocks.

Lesson review

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

1. Identify the type of environment in which sedimentary rocks are typically formed.
2. There are three types of sedimentary rocks.
   a. Which of the three is classified on the basis of grain size and shape?
   b. Name a biogenic sedimentary rock.
   c. Halite, desert roses and gypsum are examples of which type of sedimentary rock?
3. Two students are arguing over the name of a clastic sedimentary rock. One student thinks it is breccia and the other thinks it is conglomerate. To help these two students, describe the size and shape of the clasts (grains) you would expect to see in each rock type.
4. Compare the processes involved in the formation of clastic sedimentary rocks and chemical sedimentary rocks. Give specific examples for each type of rock in your answer.
5. Explain why limestone can be classified as both a chemical sedimentary rock and a biogenic sedimentary rock.
6. *Paradoxides* is a type of marine trilobite that lived about 500 million years ago. Outline two reasons that would make this trilobite a useful index fossil.

5.5 Resources in sedimentary rock

Learning intention

To be able to investigate how advances in deep Earth imaging have enabled identification of resources in sedimentary rock

Success criteria

SC 1: I can describe recent advancements in deep Earth imaging techniques.

SC 2: I can describe the various resources that can be found in sedimentary rock.

SC 3: I can create an animation to explain how imaging techniques can be used to identify different resources.



FIGURE 5.5.1 Seismic-vibrator vehicles are used in land-based exploration for oil resources.

Introduction

Deep Earth imaging has played a significant role in the identification of resources in sedimentary rocks. Some of the valuable resources that have been found are hydrocarbons, minerals, groundwater, geothermal energy and rare earth elements (Figure 5.5.1).

In this inquiry activity, you will investigate how advances in deep Earth imaging have enabled the identification of these resources in sedimentary rock.

Background

Deep Earth imaging is a scientific technique used to take pictures of what is happening deep beneath Earth's surface. Its special tools and instruments are used to gather data about the properties of rocks, minerals and fluids within Earth (Figure 5.5.1). Scientists analyse this data to create images of what is happening deep below the surface, including the underground rock and the location of underground resources like oil and gas (Figure 5.5.2). Deep Earth imaging has played a significant role in the identification of resources in sedimentary rocks.

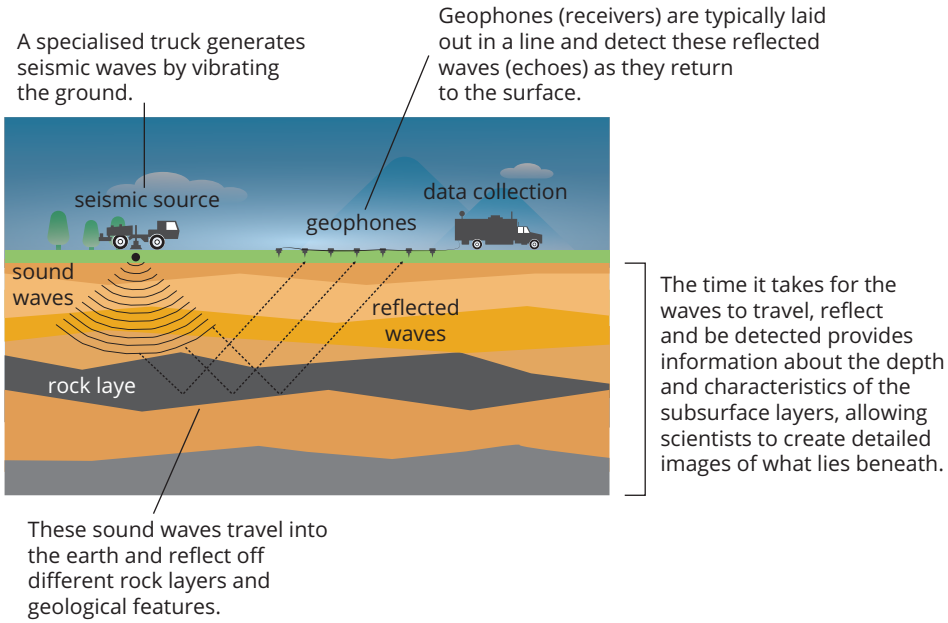


FIGURE 5.5.2 Deep Earth imaging is used to explore for hydrocarbon resources such as oil.

Aim

To create an animation explaining how deep Earth imaging technology can be used to identify resources in sedimentary rock

Plan

1. Investigate some of the recent advancements in deep Earth imaging techniques and take notes about these.
2. Explore the resources that can be found in sedimentary rock.

HINT

Useful search terms include 'deep Earth imaging technology' and 'geophysical survey techniques'.

Design

Answer the following questions to guide the design of your animation.

1. What tools will you use to create your animation?
2. What makes an animation informative and engaging?
3. What information will you include in your animation? Refer to the notes you took during the planning stage of the inquiry activity.
4. What will your key headings be?

Conduct

Create your animation using all the information you gathered during the Plan and Design stages.

HINT

Check with your teacher what animation platforms are available for use at your school.

Improve

1. What were you proud of in your animation?
2. How might you change the look and feel of your animation to make it more engaging?
3. How might you change the information to make it more informative?
4. Would you do anything differently next time?

GO TO

Toolkit sections 5.1, Methods for presenting scientific ideas, 5.2, Using scientific language and 5.3, Using artificial intelligence (AI) in science writing

Evaluate

1. What aspect of rocks were you investigating in this inquiry activity?
2. In this inquiry activity, you planned and conducted an inquiry into recent advancements in deep Earth imaging techniques. What skills did you use during this activity?

5.6 Igneous rocks

Learning intention

To understand the formation of igneous rocks

Success criteria

SC 1: I can describe how and where igneous rocks are formed.

SC 2: I can describe observable features of igneous rocks.

SC 3: I can explain the role of heat energy in the formation of igneous rocks and compare how quickly or slowly processes can occur.



FIGURE 5.6.2 Volcano Fuego (Antigua, Guatemala) erupts bringing molten lava to Earth's surface.

KEY TERMS

volcano a place where extremely hot material from inside Earth erupts at the surface
magma molten rock below Earth's surface
lava molten rock that reaches Earth's surface
igneous rock rock formed by the cooling of molten rock, e.g. basalt
extrusive igneous rock igneous rock that forms on the surface of Earth
intrusive igneous rock igneous rock that forms below the surface of Earth

Lesson overview

Earth's crust was originally formed when molten rock cooled to form igneous rock. The word 'igneous' means 'born of fire'. Molten magma and lava crystallise to form these rocks (Figure 5.6.1).



FIGURE 5.6.1 Lava cools on Earth's surface to form igneous rock.

In this lesson, you will learn how and where igneous rocks are formed, the observable features of igneous rocks and the role of heat energy in the formation of igneous rocks.

SC 1 I can describe how and where igneous rocks are formed

A **volcano** is a formation that allows extremely hot material from inside Earth to erupt at Earth's surface (Figure 5.6.2). The molten rock below Earth's surface is called **magma**, and magma reaching Earth's surface is called **lava**.

Igneous rock is formed when magma or lava cools and hardens into rock.

This can happen in different ways:

- Magma may cool on the surface of Earth, in the air, under water or underground.
- Igneous rocks that form above the ground are called **extrusive igneous rocks**.
- Igneous rocks that form when magma gets trapped underground and cools are called **intrusive igneous rocks**.

SCIENCE IN SOCIETY

Unusual types of lava

The viscosity (thickness) of lava influences the type of volcanic eruption that will occur. Lava with high viscosity will cause explosive eruptions. Less viscous, more runny lava will generally produce eruptions that are much less explosive.

The volcanoes in Hawai'i have less viscous basaltic lava. This less viscous lava can produce a very unusual form of volcanic glass if conditions are right. Sometimes, the lava erupts fountain-like from the volcano. At other times, the lava spatters over the surrounding landscape. The lava may also flow over a cliff like a waterfall into the ocean. In each of these situations, fine strands of volcanic glass are formed from stretching globules of lava, much as thin strands form when a piece of chewing gum is stretched. The strands cool very rapidly and solidify into hair-like volcanic glass. These strands are called 'Pele's hair' (Figure 5.6.3), named after Pelehonuamea, the Hawai'ian goddess of volcanoes and fire. The globules form small tear-shaped pieces of volcanic glass called 'Pele's tears'.

Pele's hair can be carried by wind some distance from the eruption site. If produced in large quantities, it can form mats on the ground.

Pele's tears tend to fall closer to the volcano's vent because they are heavier. Pele's hair can be so fine, sharp and brittle that slivers can easily penetrate skin and cause eye injuries. It can also cause respiratory injuries if inhaled.

Hawai'i is not the only volcanic region producing Pele's hair. Volcanoes in Nicaragua, Italy and Ethiopia also produce this type of volcanic glass. In Iceland, it is known as 'witches' hair'.



FIGURE 5.6.3 Strands of Pele's hair—fine, volcanic glass fibres formed from molten lava ejected into the air

SC 1 CHECK YOUR UNDERSTANDING

Where are intrusive igneous rocks formed? Compare this to extrusive igneous rocks.

SC 2 I can describe observable features of igneous rocks

As the molten rock cools into an igneous rock, it forms crystals that grow together. This causes the crystals to interlock, so the rock is hard.

Extrusive igneous rocks

Extrusive igneous rocks cool very quickly when lava is exposed to air or water. They have specific observable features.

- Large crystals do not have time to grow, so the crystals are tiny and are only visible under a microscope.
- They might have a bubbly texture as can be seen in Figure 5.6.4. This is due to trapped bubbles of gas within the lava as it cooled rapidly.



FIGURE 5.6.4 Pumice is an example of an extrusive igneous rock that trapped gas as it cooled rapidly.



FIGURE 5.6.5 Granite is an example of an intrusive igneous rock.

KEY TERMS

porphyritic the texture of intrusive and extrusive igneous rocks that have large crystals surrounded by finer crystals or grains

mineral a naturally occurring solid substance that is inorganic, has a characteristic crystalline structure and a fairly constant chemical composition



FIGURE 5.6.6 Andesite has a porphyritic texture with crystals of varying size.



FIGURE 5.6.7 Obsidian (volcanic glass) is an extrusive igneous rock with very few crystals as it cooled very rapidly.

Some examples of extrusive igneous rocks are basalt, obsidian (volcanic glass), scoria and pumice.

Intrusive igneous rocks

Intrusive igneous rocks cool slowly because they cool underground. They tend to have large crystals that can be seen without the help of a microscope. The large crystals form because the slow cooling means that large crystals have time to grow. Some examples of intrusive igneous rocks are dolerite, gabbro and granite (Figure 5.6.5).

Porphyritic igneous rocks

The term **porphyritic** is used to describe the texture of igneous rocks that contain crystals of very different sizes. Some are microscopic due to fast cooling while some are large due to slow cooling. Both intrusive and extrusive igneous rocks can be described as porphyritic.

Porphyritic igneous rocks are formed from rising magma. The larger crystals develop first as the magma cools slowly beneath the ground, then, as it erupts, it creates small, non-visible grains. An example of a porphyritic igneous rock, andesite, is shown in Figure 5.6.6.

Making observations

When describing igneous rocks, you will observe their texture and colour. For example, their texture could be rough or smooth and the varying size of the crystals should be noted. The colour of the rock indicates what **minerals** it may contain.

SC 2 CHECK YOUR UNDERSTANDING

An igneous rock sample has been identified as being porphyritic. What does this tell you about:

a where it formed?

b the size of its crystals?

SC 3 I can explain the role of heat energy in the formation of igneous rocks and compare how quickly or slowly processes can occur

Heat energy plays an important role in how igneous rocks are formed.

When magma reaches the surface to become lava, it cools very rapidly as it loses heat energy to the surrounding environment, especially if the eruption happens under water. This produces extrusive igneous rocks. When lava cools quickly, it forms either very small crystals or no crystals at all (Figure 5.6.7). This is because the crystals have not had enough time to grow during the rapid cooling.

Magma that does not reach the surface cools much more slowly and forms intrusive igneous rocks. In this case, the heat energy is absorbed slowly by the surrounding rock in Earth's crust. Larger crystals form in rocks when cooling occurs more slowly (Figure 5.6.8). This happens because particles within the magma can move around in a liquid state and keep adding to nearby crystals giving them time to grow.

SC 3 CHECK YOUR UNDERSTANDING

Describe what happens to heat energy in lava when it reaches Earth's surface.



FIGURE 5.6.8 Diorite's large crystals formed when magma beneath Earth's surface cooled very slowly.

Lesson review

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

1. Explain the difference between intrusive igneous and extrusive igneous rocks.
2. If you find an igneous rock with large, visible crystals, what can you infer about its formation?
3. You are examining igneous rock samples to identify their features.
   - a. List the observable features you would look for in igneous rocks.
   - b. Explain how the cooling rate affects the texture of igneous rocks.
   - c. Compare the textures of intrusive and extrusive igneous rocks.
   - d. Evaluate the importance of colour in identifying igneous rocks.
   - e. One of the rock samples has crystals of varying sizes—some are visible to the naked eye and others are microscopic. What type of igneous rock is this likely to be?
4. Explain how heat energy affects the formation of igneous rocks.
5. A fine-grained igneous rock with a bubbly texture has been found on the beach.
   - a. Which type of igneous rock is this specimen most likely to be?
   - b. Is the molten material from which it formed likely to be lava or magma?
   - c. Describe the rate at which heat energy would have been lost as this rock cooled.
   - d. What is the likely cause of the bubbly texture?
   - e. Suggest the name of the igneous rock.

5.7 Metamorphic rocks

Learning intention

To understand the formation of metamorphic rocks

Success criteria

SC 1: I can describe how and where metamorphic rocks are formed.

SC 2: I can describe examples of specific metamorphic rocks and their parent rock.

SC 3: I can explain the role of heat energy and force in the formation of metamorphic rocks and compare how quickly or slowly processes can occur.



FIGURE 5.7.1 The Marble Caves in Chile have been formed from metamorphosed limestone.

KEY TERM

metamorphic rock rock formed when temperature and/or pressure alter existing rock

Lesson overview

All rocks can be altered by heat and/or pressure to form metamorphic rocks. Even metamorphic rocks can be metamorphosed. This process turns ordinary limestone into beautiful marble (Figure 5.7.1), and soft sandstone into hard quartzite.

In this lesson, you will learn about the formation of metamorphic rocks, what a parent rock is, and the role of pressure and heat energy in the formation of metamorphic rocks.

SC 1 I can describe how and where metamorphic rocks are formed

When large amounts of heat energy or pressure are applied to rocks, the properties of the rock can change. This is how **metamorphic rocks** are formed.

Both physical and chemical changes can occur when rocks are metamorphosed. Crystals can transform into crystals of new minerals (recrystallisation). Crystals can grow into flattened sheets. Bands of different minerals form when crystals are squashed flat by forces within Earth while they are hot.

Scifile

Gemstones

Many gemstones, such as emerald and garnet, form in metamorphic rocks through the process of recrystallisation. The intense heat and pressure create the perfect conditions for these beautiful minerals to grow. Trace elements give the gemstones their different colours. For example, sapphire and ruby are varieties of the same mineral corundum, but ruby's red colour is due to traces of chromium in its structure. Sapphire's colours come from traces of elements such as iron, nickel and titanium.





There are three types of metamorphism.

Regional metamorphism

In **regional metamorphism**, the rock is affected by both heat and pressure. Most often, regional metamorphism occurs over large areas due to the collision of tectonic plates (Figure 5.7.2).



FIGURE 5.7.2 Slate, when affected by regional metamorphism, becomes schist.

Contact metamorphism

In **contact metamorphism**, the rock is mainly affected by heat. Most often, contact metamorphism occurs due to magma cutting through surrounding rock (Figure 5.7.3).

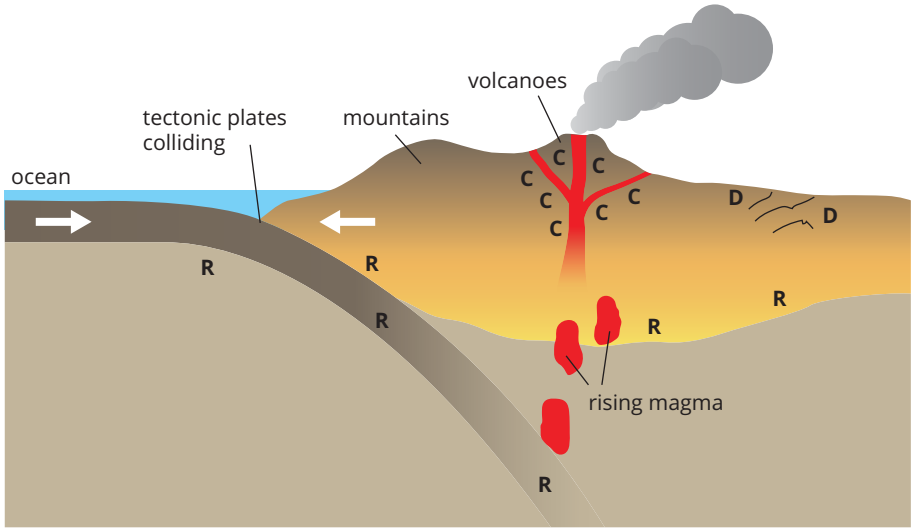


FIGURE 5.7.3 Limestone, when affected by contact metamorphism, becomes marble.

Dynamic metamorphism

In **dynamic metamorphism**, the rock is mainly affected by pressure. Most often, dynamic metamorphism occurs in areas where the movement of the crust causes rocks to drag past each other. For example, this might occur near faults (Figure 5.7.4).

Figure 5.7.5 shows the areas in Earth's crust where the three types of metamorphic rock are formed.



R regional metamorphism (heat and pressure)

C contact metamorphism (mainly heat)

D dynamic metamorphism (mainly pressure)

FIGURE 5.7.5 Areas in Earth's crust where the three types of metamorphism occur



FIGURE 5.7.4 Schist, when affected by dynamic metamorphism, becomes gneiss.

SC 1 CHECK YOUR UNDERSTANDING

Name the three types of metamorphism. For each, state whether it is mainly heat, mainly pressure or both heat and pressure that causes rocks to metamorphose.

SC 2 I can describe examples of specific metamorphic rocks and their parent rock

Parent rocks

KEY TERMS

parent rock a rock that experiences metamorphism, or changes form, to become a new kind of rock

foliated a process where minerals under pressure realign and the rock develops layers or bands

Metamorphism changes the original rock or **parent rock** into a completely new rock. The parent rock can be sedimentary, igneous or metamorphic.

When the minerals in a rock are forced into layers, the rock is said to be **foliated**. These bands of minerals can also have a wavy pattern when pressure is applied and squeezes the layers. Metamorphic rocks are either foliated or non-foliated.

Foliated metamorphic rocks will split along lines (known as cleavages) that are parallel to the minerals that make up the rock.

Non-foliated rocks have no cleavage or banding and are typically harder rocks. Non-foliated rocks occur when heat is high, but pressure is low or equal on all sides.

Foliated metamorphic rocks

The following are examples of metamorphic rocks that are foliated.

Shale (mudstone) is the sedimentary parent rock that forms slate under pressure and heat.

Slate is a foliated metamorphic rock. Note the cleavage lines through the rock shown in Figure 5.7.6. Slate is still fine-grained like its parent rock.



FIGURE 5.7.6 Shale is metamorphosed to foliated slate.

If slate is subject to more pressure and higher temperatures, it will change again to form schist (Figure 5.7.7). New minerals are formed, the crystals are larger, and the rock remains a foliate.



FIGURE 5.7.7 Slate is metamorphosed to form schist.

With even greater pressure and temperature, schist will change again into gneiss and the crystals may form into bands (Figure 5.7.8). The rock remains a foliate.



FIGURE 5.7.8 Schist is metamorphosed to form gneiss.

Non-foliated metamorphic rocks

The following are examples of metamorphic rocks that are non-foliated.

Quartzite is much harder than its parent rock sandstone (Figure 5.7.9). Sandstone will shatter into many individual grains of sand whereas quartzite will break across the grains. Quartzite is non-foliated.

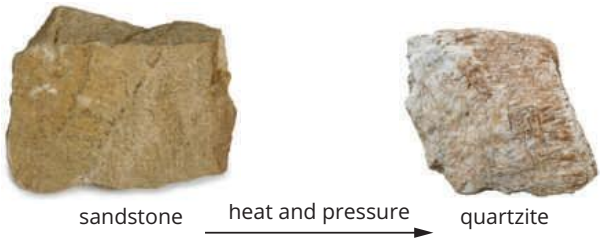


FIGURE 5.7.9 Sandstone is metamorphosed to form quartzite.

Marble is formed from metamorphosed limestone or dolomite. Marble has many colour variations, including white (Figure 5.7.10), red, black, grey, pink, mottled and banded. Marble is non-foliated.

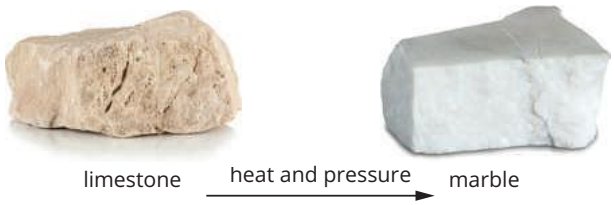


FIGURE 5.7.10 Marble is metamorphosed from limestone, one of its parent rocks.

SC 2 CHECK YOUR UNDERSTANDING

Shale can undergo several stages of metamorphism to form the metamorphic rock gneiss.

a Identify the parent rock in this process.

b Sketch a flow chart to show the stages of metamorphism of gneiss from the parent rock.

c Is gneiss an example of a foliated or a non-foliated metamorphic rock?

SC 3 I can explain the role of heat energy and force in the formation of metamorphic rocks and compare how quickly or slowly processes can occur

Metamorphic rocks are formed by heat and pressure. The amount of heat and pressure on a rock changes its final appearance and characteristics.

The heat energy applied to the rocks does not melt them but causes changes to the mineral composition and crystal structure. The temperatures required for these chemical changes are greater than 150°C. If the amount of heat energy becomes too great, then the rock may melt and thus become magma, creating new igneous rock instead. The application of force during movements in Earth's crust increases the pressure on the rocks, which also causes chemical changes in existing rock.

The chemical changes caused by the applied heat energy and pressure include:

- the recrystallisation and realignment of minerals
- a change in the mineral composition and texture of the rock
- the formation of new minerals.

Forces and foliation

When the minerals in a rock are forced into alignment, the rock is said to be foliated (Figure 5.7.11).

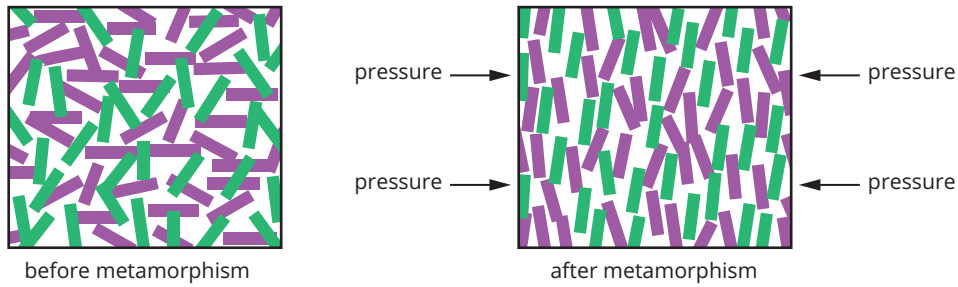


FIGURE 5.7.11 Pressure applied in the crust forces minerals to align to form foliated rocks.

Foliated metamorphic rocks are formed under high pressures from shearing forces. Shear forces describe forces that act in opposite directions. These forces cause parallel layers or cleaves to form in the rock.



FIGURE 5.7.12 A non-foliated quartzite vein is surrounded by solidified igneous gabbro.

Heat energy and non-foliation

Non-foliated rocks are formed under high heat but low or equal pressure. This prevents the mineral crystals from forming cleaves or splits, and the overall density and strength of the rock are increased.

Contact metamorphism occurs when rock is heated up by an intrusion of hot magma. Contact metamorphism does not involve the squashing of rock layers, so these rocks do not have foliated textures.

Figure 5.7.12 shows a vein of non-foliated quartzite surrounded by gabbro, the intrusive igneous rock that caused the contact metamorphism.

Heat energy affects the speed of metamorphism

Metamorphic processes work on very long timescales. Rocks experiencing lower heat and pressure will metamorphose more slowly than those exposed to higher heat and pressure. Regional metamorphism will occur more quickly than contact or dynamic metamorphism because the combination of high heat and high pressure will increase the rate of transformation.

SC 3 CHECK YOUR UNDERSTANDING

Identify the type of metamorphic rock most likely to form when strong shear forces are applied to rock in Earth's crust.

Lesson review

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

1 Describe how metamorphic rocks typically form.

2 Compare the formation environments of contact metamorphism and regional metamorphism.

3 If you find a rock that has been subjected to high pressure but low temperature, what type of metamorphic rock might it be?

4 Compare the parent rocks and resulting metamorphic rock types for quartzite and schist.

5 You are studying the formation of metamorphic rocks under different conditions of heat and pressure.

- **a** Describe the role of heat energy in the metamorphic process.
- **b** Explain how pressure influences the texture of metamorphic rocks.
- **c** Compare the formation processes of non-foliated and foliated metamorphic rocks.
- **d** A metamorphic rock is foliated but the crystals are small. Identify the type of metamorphism this rock has most likely undergone.

6 Slate is a metamorphic rock that has been used for centuries as roof, floor and wall tiles, and as the base for billiard tables. Outline the characteristics of slate that make it suitable for these purposes. Consider grain size, foliation and hardness in your response.

5.8 The source of metamorphic rocks

Learning intention

To be able to investigate the source of metamorphic rocks

Success criteria

SC 1: I can use a dichotomous key to identify igneous, sedimentary and metamorphic rocks.

SC 2: I can use observations and secondary data to match the metamorphic rocks to their parent rocks.

SC 3: I can describe changes that have occurred to the properties of rocks because of the production of the metamorphic rock.

KEY TERM

dichotomous key a key with two choices at each stage

Introduction

Metamorphic rocks, such as the marble shown in Figure 5.8.1, are formed from other rocks when placed under pressure and/or heat. In this practical investigation, you will investigate the source of metamorphic rocks by using an identification tool called a dichotomous key.



FIGURE 5.8.1 Marble formed from the parent rock of limestone.

Background

Dichotomous keys are used in classification processes. They give the user two choices at each point in the procedure. Dichotomous keys can be used to classify rocks.

SkillBuilder

Classifying rocks

Using dichotomous keys to classify rocks

Do the following when observing and classifying rocks.

1. Spray the rock with water to make it easier to see any contrasting colours.
2. View the rock through a magnifier.
3. Use a ruler to estimate the size of any clasts or crystals.

Note that very fine-grained rocks may be difficult to classify without extra techniques such as taking a thin slice of the rock to observe under a microscope.

Dichotomous key for classifying rocks

1	Rocks have crystals—go to 2. Rocks do not have crystals—go to 6.
2	Rocks are made entirely of interlocking crystals. *Igneous*—go to 3. Rocks are not made entirely of interlocking crystals. *Metamorphic*—go to 10.
3	Rocks have crystals large enough to see using a hand lens. *Igneous intrusive*—go to 4. Rocks are crystalline but their crystals are difficult to see using a hand lens. *Igneous extrusive*—go to 5.
4	Rocks are dark and dense. *Igneous, intrusive and mafic* (rich in magnesium and iron), e.g. gabbro Rocks are neither dark nor dense. *Igneous, intrusive and felsic* (rich in feldspar and silicon), e.g. granite, pegmatite

5	Rocks are dark and dense. *Igneous, extrusive and mafic* (rich in magnesium and iron), e.g. basalt Rocks are neither dark nor dense. *Igneous, extrusive and felsic* (rich in feldspar and silicon), e.g. rhyolite
6	Rocks are non-crystalline and are made of clasts (pieces or chunks). *Sedimentary, clastic*—go to 7. Rocks are non-crystalline but are not made of clasts. *Sedimentary, biogenic*, e.g. limestone, chalk, coal
7	Rocks have large clasts—go to 8. Rocks do not have large clasts—go to 9.
8	Rocks have large clasts that are rounded. *Sedimentary, clastic large grained*, e.g. conglomerate Rocks have large clasts that are not rounded. *Sedimentary, clastic large grained*, e.g. breccia
9	Rocks have medium rounded clasts. *Sedimentary, clastic medium grained*, e.g. sandstone Rocks have clasts that are less than medium size. *Sedimentary, clastic fine grained*, e.g. siltstone, mudstone
10	Rocks are foliated (or banded). *Metamorphic, foliated*, e.g. slate, schist and gneiss Rocks are not foliated (or banded). *Metamorphic, non-foliated*, e.g. quartzite and marble

Worked example

Classifying rocks

This worked example uses the dichotomous key from the SkillBuilder to classify a rock sample.

Problem

Use the dichotomous key to classify the unknown rock sample to the right. Note that each bar on the scale is 1 cm.



Solution

Thinking	Working
Does the rock have crystals?	Yes, go to 2.
Are the crystals interlocking?	Yes, go to 3.
Can you see the crystals using a hand lens?	Yes, go to 4.
Is the rock dark and dense?	The rock is neither dark nor dense—it is light in colour. This means it is an igneous, intrusive and felsic rock (rich in feldspar and silicon), such as granite or pegmatite. (Note: The sample is granite.)

Try yourself

Classifying rocks

Use the dichotomous key to classify this rock. Note that each bar on the scale is 3 cm.



Aims

To classify unknown rock samples as igneous, sedimentary or metamorphic

To compare metamorphic rocks with their parent igneous, sedimentary and metamorphic rocks

Materials

Task 1

- numbered but unlabelled rock samples
- stereo microscope and/or hand lens

Task 2

- labelled rock samples in containers: gneiss, granite, limestone, marble, quartzite, sandstone, schist, shale, slate
- stereo microscope and/or hand lens

Method

Task 1

1. Choose a numbered rock sample. Your first task is to describe the characteristics of the rock.
2. Use your microscope and/or hand lens to take a closer look. Then, using the dichotomous key, decide whether it is igneous, sedimentary or metamorphic. Record your reasons in your results table. If you feel confident, try to name the rock.
3. Repeat step 2 for each rock.
4. Record all observations in your results table.

Task 2

1. Use the microscope and/or hand lens to examine the rock samples.
2. Use the information in the 'Metamorphic rocks' lesson, and any other information available to you, to match each metamorphic rock to its parent rock.

HINTS

It is possible that a particular rock is the parent rock for more than one metamorphic rock.

It is also possible that a metamorphic rock may have more than one parent rock.

3 For each pair of rocks, write the name of the parent rock first and describe its characteristics, including its rock type. Then, do the same for the metamorphic rock.

4 For each metamorphic rock, describe the characteristics that enable you to decide it is metamorphic.

5 Describe changes that have occurred in each metamorphic rock as it altered from its parent rock.

Results

Copy the results tables below into your notebook and record your observations.

Task 1

Rock number	Description	Classification	Rock name

Task 2

	Parent rock	Description	Metamorphic rock	Description
Pair 1				
Pair 2				
Pair 3				
Pair 4				
Pair 5				

Rock name	Reasons you have decided it is metamorphic	What changes occurred to make it metamorphic?

Conclusion

Summarise how you were able to classify rock samples (Task 1) and determine the parent/metamorphic rock relationships (Task 2).

Evaluation

Evaluate your practical investigation by considering how you could improve the process of classification.

5.9 The rock cycle in action

Learning intention

To understand how environmental changes affect the rock cycle

Success criteria

SC 1: I can compare the formation of different types of rock within the rock cycle.

SC 2: I can predict how environmental changes will affect a rock's structure based on the rock cycle.

SC 3: I can predict and explain locations where specific types of rocks are found.

Lesson overview

Rocks are not alive, but they have been constantly changing since Earth formed. All landscapes, and the rocks in them, are the result of processes that include weathering and erosion (Figure 5.9.1), formation of new rocks, and changes brought about by heat and pressure. The rock cycle is a model that outlines these processes and the resultant changes to rock types. In this lesson, you will learn about the formation of different types of rock within the rock cycle and the impact of environmental factors on the structure of rocks.



FIGURE 5.9.1 Water is one of the most important agents of weathering and erosion in landscapes.

SC 1 I can compare the formation of different types of rock within the rock cycle

The rock cycle

KEY TERM

rock cycle a model geologists use to explain the endless cycle of change that rocks undergo

Since Earth was formed, rocks have been continually changing. The **rock cycle** is a model used by scientists to explain the endless cycling of rocks and rock types.

Changes constantly occur throughout the rock cycle, which affect the structure of rocks and assists in the formation of new rocks. The rock cycle diagram in Figure 5.9.2 shows that a range of processes such as erosion, deposition, melting, heat and/or pressure, and crystallisation cause changes to the structure of rocks. Some of these occur deep in Earth's lithosphere where there are higher levels of heat and pressure. Others are the result of environmental changes on Earth's surface itself.

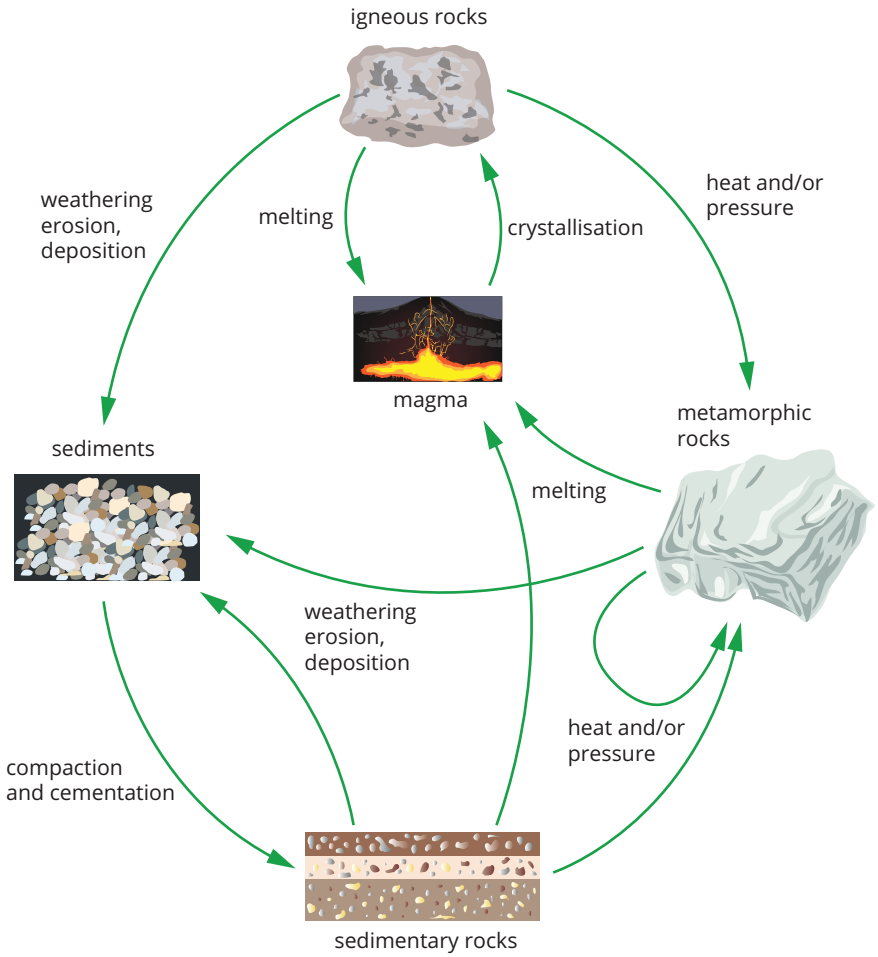


FIGURE 5.9.2 A more detailed version of the rock cycle showing geological processes and changes to rock type

The processes that form sedimentary, igneous and metamorphic rocks are a continuous cycle that began when Earth was first formed. It is important to note that the cycle does not occur in one direction, nor include all three rock types as is often depicted in images of the rock cycle. It is possible for igneous rocks to melt and cool, forming new igneous rocks. A metamorphic rock may undergo further heat and/or pressure to form a new type of metamorphic rock. Sedimentary rocks may undergo weathering, erosion, compaction and cementation, and so form a new sedimentary rock. A sedimentary rock may metamorphose when subjected to high levels of heat and/or pressure, then go through uplift and erosion to form a new sedimentary rock.

Scifile

Climate impact

Climate changes can speed up or slow down the rock cycle. For example, more rainfall can increase weathering and erosion, while a dry climate can slow these processes down. Higher temperatures speed up chemical weathering reactions. More extremes in temperature also accelerate physical weathering.

SC 1 CHECK YOUR UNDERSTANDING

Identify the geological processes that can change:

a an igneous rock into a sedimentary rock

b a sedimentary rock into an igneous rock

c a metamorphic rock into an igneous rock

d a sedimentary rock into a metamorphic rock

e a metamorphic rock into a metamorphic rock

f a metamorphic rock into a sedimentary rock.

SC 2 I can predict how environmental changes will affect a rock's structure based on the rock cycle



FIGURE 5.9.3 Onion skin weathering is a type of physical weathering caused by rapid temperature changes.



FIGURE 5.9.4 Chemical weathering of limestone



FIGURE 5.9.5 Trampling by hard-hooved animals like cattle causes weathering of the ground surface.

KEY TERM

humus dark material in soils produced by the decomposition of plant or animal remains

Environmental changes on Earth's surface can affect igneous, metamorphic and sedimentary rocks. The processes influenced by environmental changes include rates of weathering, erosion and deposition.

Weathering

The term 'weathering' describes the processes that affect the structure of rocks and breaks them down into smaller pieces.

Physical weathering

Agents of physical weathering include wind, rapid changes in temperature, water, ice and salt crystallisation. Figure 5.9.3 shows the effects of rapid temperature changes causing onion skin weathering of rock. This occurs in arid regions where temperatures can drop below zero at night, causing water to freeze in cracks in the rock and force particles apart.

Chemical weathering

Chemical weathering occurs when water with dissolved chemicals from the soil and air reacts with the rock, causing it to change colour or weaken. Figure 5.9.4 shows the effects of carbonic acid (carbon dioxide dissolved in water) on limestone. Chemical weathering of rocks also occurs when high levels of pollutants from the burning of fossil fuels, such as sulfur dioxide and nitrogen oxides, combine with water in the atmosphere to form acid rain.

Biological weathering

Biological weathering is commonly caused by the actions of plants and animals. For example, plant roots grow through cracks and split rocks, while plant enzymes and acids from **humus** can dissolve rocks. Deforestation reduces the rates of biological weathering by plants. Trampling by animals can also affect rock structure. As more land is occupied by hard-hooved livestock, weathering of the surface increases (Figure 5.9.5). Burrowing by animals such as rabbits into rocks can also break them down.

Erosion

Erosion is the transportation of small rock particles created by weathering. Water, wind, gravity and ice (agents of erosion) move the particles away from the site of weathering (Figure 5.9.6).

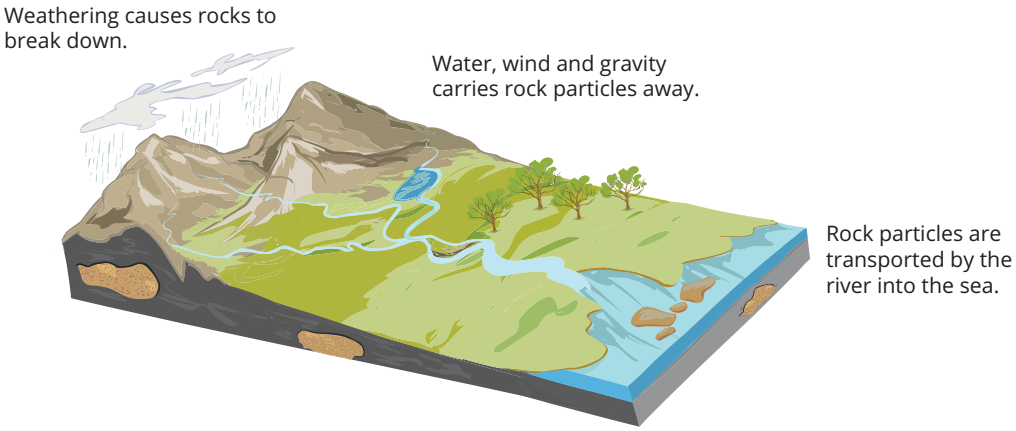


FIGURE 5.9.6 Erosion transports particles from the site of weathering to where they are deposited.

Rates of erosion are influenced by weather and climate. For example, episodes of high wind and rainfall such as with cyclones increase the rate at which weathered material is moved. Increased rainfall increases the incidence of landslides. In regions where conditions are becoming drier, high winds result in the transportation of more weathered material. Climate change causing glaciers to melt increases the erosion rate of meltwater and reduces erosion by ice.

Deposition

The rock particles transported through erosion are deposited when the agents of erosion (water, wind, gravity or ice) lose energy and slow. This forms a layer of sediments. For example, when water slowed in the Colorado River, USA, sand and rocks were deposited in the riverbed (Figure 5.9.7).



FIGURE 5.9.7 Deposits of rock and sand in the Colorado River, USA

SC 2 CHECK YOUR UNDERSTANDING

Australia's climate is expected to dry with climate change. Predict two impacts this might have on the rock cycle in Australia.

SC 3 I can predict and explain locations where specific types of rocks are found

Where specific types of rocks are found

Most of the rocks in Australia are either igneous or sedimentary rocks. However, metamorphic rocks can be found in some regions of Australia, particularly in the Pilbara and Yilgarn in Western Australia where ancient gneiss rock formations are common. Igneous rocks formed during volcanic activity and mountain building; for example, those on the east coast when the Great Dividing Range formed. Sedimentary rocks formed when large parts of Australia's interior were a shallow sea. Some of Australia's well-known landmarks are the result of environmental changes to these rock types.



FIGURE 5.9.8 Mount Kosciuszko is part of a mountain range formed when igneous granite was uplifted.

Igneous landmarks

Mount Kosciuszko in New South Wales is formed of igneous granite rocks. Igneous rocks are often present in mountain ranges where volcanic activity has occurred, or where there has been large-scale uplift of igneous rock formed deep in the crust, as occurred in the Australian Alps. The craggy appearance of the rocks in the Mount Kosciuszko landscape (Figure 5.9.8) is due to cracks that formed by weathering from water and ice. The scattered rocks are due to the erosive action of melting snow and gravity transporting some boulders downhill.

Western Australia's Wave Rock (Figure 5.9.9) is formed from porphyritic igneous granite with embedded crystals. Most of the stripes of colour on the rock are due to chemical weathering, but the black and brown stripes are due to discolouration from algae that lives on the rock. Water erosion has undercut the base.



FIGURE 5.9.9 Wave Rock is a landmark formed from porphyritic igneous granite.

Sedimentary landmarks

Uluru in the Northern Territory is the remnant of sediments eroded from an ancient mountain range (Figure 5.9.10). The sediments were buried and compressed to form harder rock, resulting in the sedimentary arkose rock of Uluru. Arkose is made from sandstone and feldspar.

Figure 5.9.11 shows some of Victoria's Twelve Apostles, sea stacks made of sedimentary limestone. The rocks began forming hundreds of millions of years ago when pieces of sediment such as shells, coral and animal skeletons settled at the bottom of the ocean, layer upon layer. These sediments gradually compressed together to turn into limestone. Weathering and erosion have created the sea stacks.



FIGURE 5.9.10 Uluru is the remnants of the sedimentary rock arkose.



FIGURE 5.9.11 Sedimentary limestone forms the Twelve Apostles.

Metamorphic landmark

Trephina Gorge is in the East MacDonnell Ranges of the Northern Territory (Figure 5.9.12). This gorge has sheer cliffs of metamorphic quartzite. The quartzite was once sandstone, but heat and pressure metamorphosed the sandstone to quartzite, which later uplifted to form the MacDonnell Ranges. Weathering and erosion have created the gorge.



FIGURE 5.9.12 The MacDonnell Ranges formed when metamorphic quartzite was uplifted.

SC 3 CHECK YOUR UNDERSTANDING

Identify the rock type or types that are the most abundant in Australia.

Lesson review

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

1 Outline the five stages involved in the formation of sedimentary rocks.

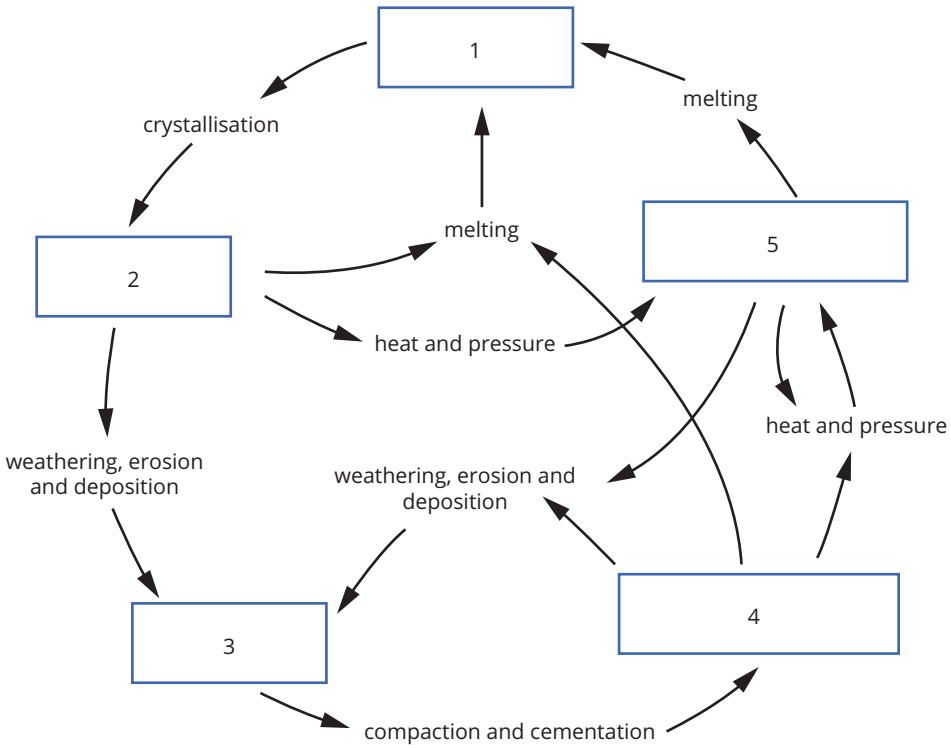
2 Compare the role of heat in the formation processes of igneous and metamorphic rocks.

3 Compare the effects of weathering and erosion on igneous rocks in a tropical climate versus a desert climate.

4 Identify the stages of the rock cycle labelled 1 to 5.

5 You are mapping the distribution of different rock types in various geological settings.

- **a** Identify the types of rocks you would expect to find in a volcanic region.
- **b** Explain the processes that lead to the formation of these rocks.
- **c** Predict the types of rocks found in a river delta and explain their formation.
- **d** Evaluate the role of uplift on the distribution of all three rock types.



6 'Australia has the best sand beaches in the world because the landscape is so old.'

Evaluate this statement, considering the role of the rock cycle in creating these beaches.

5.10 Mineral resources in Australia

Learning intention

To be able to explain how the mining of Australian mineral resources influences/impacts society

Success criteria

SC 1: I can describe how groups of First Nations Australians use quarrying to access rocks and minerals.

SC 2: I can describe the impacts of the Australian mining industry on Australian society.

SC 3: I can explain the impacts of Australian society on the Australian mining industry.



FIGURE 5.10.1 The Ochre Pits in Tjoritja/West MacDonnell National Park in the Northern Territory are utilised by the Arrernte people.

Introduction

Australia is rich in valuable mineral resources, including iron ore, gold and alumina. Australia's mineral resources have played, and continue to play, a major role in Australia's economy. Traditional mining has also been carried out by First Nations Australians over thousands of years (Figure 5.10.1).

Understanding the differing aims and processes of modern mining compared to traditional methods helps highlight the historical and cultural significance of First Nations Australians' mining. This knowledge also supports ongoing dialogue between First Nations Australians and the commercial mining industry.

Australian society influences the country's mining practices through social expectations and values, environmental awareness, activism and advances in technology.

In this inquiry activity, you will investigate the impacts of mining practices on Australian society, and vice versa.

Background

First Nations Australians have engaged in mining for many generations, extracting resources like ochre and the minerals needed for tools, artwork and cultural practices. First Nations mining operations are generally localised, small scale and deeply embedded in their cultural and spiritual traditions. Their practices are guided by a deep understanding of the local ecosystem.

In contrast, commercial mining companies operate on a much larger scale and are driven by profit, targeting valuable building, mineral and hydrocarbon resources such as sandstone, iron ore, gold and coal. These operations can have significant environmental impacts, including water pollution, habitat destruction and the potential displacement of First Nations communities from their traditional lands.

Commercial mining operates under the legal framework of the *Native Title Act* 1993, which requires negotiation and agreement with First Nations communities who hold native title rights over the land.

Commercial mining in Australia began in the late eighteenth century and focused on extracting precious minerals like gold and silver, often in small-scale, manually intensive operations. The mid-nineteenth-century Gold Rush in regions including Victoria and New South Wales resulted in large-scale commercial gold mining, causing population growth and the establishment of mining towns.

In the late nineteenth century, advances in mining technology led to the expansion of commercial operations to include other valuable minerals such as copper and iron ore. Commercial mining of mineral resources today continues to be shaped by changing societal expectations and environmental awareness.

Aim

The aim of this activity is to explore how mineral resources have been extracted in Australia. Once your area of research has been identified, you may need to access information relating to methods used, how mining affects people and the environment, and how the ideas and needs of society at the time have influenced different approaches to mineral extraction in Australia.

Possible areas for investigation are:

- how (at least two) groups of First Nations Australians use quarrying to access rocks and minerals
- how the commercial mining industry has evolved over time, and the impact of this industry on the development of Australian society
- how Australian society has influenced the commercial mining industry.

Your teacher will allocate your group a research topic. You will then present the findings of your inquiry to your class.

Plan

Working in your groups, discuss the research task you have been allocated and what you will need to find out. For example, depending on your topic, it may help to consider which First Nations groups to research based on the availability of relevant information, why rocks and minerals are mined, how mining is carried out and why attitudes towards mining may have changed. Take notes on your discussion.

Design

1 Identify the research questions that will help you complete your task, as well as possible sources of information and who is responsible for them. Record this information in a table. An example has been provided to get you started.

Research question	Sources of information	Who will research this?
Why do First Nation Australians quarry for rocks and minerals?	Internet, textbooks, other reference books	Jessie

2 Agree on how the research will be conducted and when it should be completed.

HINTS

You will need to carry out research for this inquiry activity. When sourcing information from the internet, you must decide whether the content you find is helpful and accurate. Consider the following questions when undertaking internet research.

1 Does it answer my question? Only record information that links directly to your research question.

2 Is this a credible author or source? Factual information is more credible from official organisations, government sites and authors with relevant qualifications and experience.

3 Can I find other sources to support the information I have found? If multiple sources provide the same answers, the information is more likely to be reliable.

GO TO
Toolkit sections 2.3, Sites on Country/Place and 5.3, Using artificial intelligence (AI) in science writing

Conduct

1. State your assigned research question(s).
2. Use a table like the one below to summarise your research. Be sure to include details about the sources of your information such as website addresses or book titles.

Research notes	Source information

HINTS

To answer the Improve questions, consider the following.

Group collaboration: Was everyone clear on their role? Did everyone contribute?

Responding to your research question: Were there any gaps in your response that needed further research? Did you make a note of these in your presentation?

Mode of communication: How did you choose to communicate your findings? For example, did you use a poster or a slideshow presentation when showing it to the class? Discuss whether you believe extra visual aids would have been useful in your presentation.

References and acknowledgements: Did you include references.

3. Review your findings and refine them to ensure they answer your assigned research question(s). Record the key points, ensuring your research includes examples.
4. Return to your group to discuss your topic as a whole. Does everyone agree that all the research questions have been answered?
5. Collate the group's information into a report or presentation and deliver it to your class.

Improve

1. What worked well during your group task?
2. What needed improvement?
3. What would you change about how your group approached the task?

Evaluate

1. What was the most important thing you learnt from your research?
2. What did you learn from the information presented by other groups? Write down three main points.
3. How did your attitudes towards mining change because of the research?

5.11 The environmental and economic effects of mining

Introduction

The mining industry is vital to Australia's economy. However, the mining industry has a huge environmental impact. Mining needs large areas of land for resource extraction, major transport networks and a large volume of water for the extraction and treatment processes.

Once mining of the land has finished, rehabilitation programs can be used to return the landscape to recreational or farming use. Figure 5.11.1 shows a walking trail through a eucalypt forest replanted on a rehabilitated coal mine site in New South Wales.

In this practical investigation, you will use chocolate chip cookies to model the mining and rehabilitation processes involved in the resources industry.

Learning intention

To be able to model, describe and analyse economic and environmental impacts of mining in Australia

Success criteria

SC 1: I can model the economic and environmental impacts of mining.

SC 2: I can analyse how the mining of ores and minerals impacts local environments.



FIGURE 5.11.1 Native eucalypt species have been planted on a mine rehabilitation site.



FIGURE 5.11.2 A chocolate chip biscuit can be used to model a potential mine site.

Background

Mining companies will mine a resource if the price they receive for the mineral is greater than the cost to produce it.

Aim

To model the mining process by using a chocolate chip biscuit as the mining site (Figure 5.11.2); the valuable 'mineral' the biscuit contains is chocolate

Plan

1. Design a technique to extract the most amount of mineral from the mine in 5 minutes.
2. Extracting the minerals must be done in a way that causes the least amount of damage to the environment.
3. You must balance the costs and benefits of the mine and select tools within a budget of $20.
4. Each full chocolate chip you extract is worth $3.50.

Materials

- $20 of play money per group
- chocolate chip biscuits with lots of chocolate chips
- chocolate chip biscuits with fewer chocolate chips
- paperclips
- toothpicks
- dowel or old pencil
- weighing balance

Material costs

- high-quality mining site: $8
- low-quality mining site: $4
- paperclip: $6
- toothpick: $2
- dowel or old pencil: $4

SAFETY NOTE

- Do not eat or taste any 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

1. Check the available equipment and brainstorm some possible methods to extract chocolate chips from a biscuit.
2. In a small group (two or three students), plan a strategy to extract the chocolate chips from the biscuit.
3. Decide which tools and mine(s) you will work with. Remember that you have a total of $20 to spend on materials and your mine site(s).
4. Weigh the biscuit before you begin mining and record this mass in a table like the one shown in the results section.
5. Wait for your teacher to start the 5-minute timer, and then commence mining.
6. Carefully put each extracted chocolate chip aside.
7. Ensure the mine site is cleaned up or risk a $4 fine.
8. Determine the average mass of chocolate chips in a biscuit and the amount of 'waste' left behind.
9. Tally your total mining costs, earnings from the extracted chocolate chips and any clean-up fee to determine whether a profit has been made.

HINT

To determine an average, you should test more than one biscuit or share your results with other groups.

Results

Copy the results table below into your notebook and record your observations.

Brand of biscuit	Average mass of biscuit (g)	Average mass of chocolate chips after extraction (g)	Average mass of waste material (g)

Conclusion

1. Comment on whether you made a profit in your mining operations. Compare the average mass of each group's biscuit(s) and the mass of chocolate chips extracted.
2. Compare the average mass of the chocolate chips extracted and the average mass of waste material. Outline why the volume of the waste material is important in the mining industry.

Evaluation

Explain how you could have made a better choice of mine site (biscuit) before you mined. Outline how this would reduce environmental impacts.

5.12 Sustainable mining practices

Lesson overview

Sustainability has become an increasingly important priority in the mining industry in Australia in recent years. This has led to a range of innovative practices that aim to reduce the environmental impact of mining operations and improve social outcomes whilst still achieving profits.

In this lesson, you will learn how economic, social and environmental sustainability priorities have led to innovative practices in mining in Australia.

SC 1 I can describe various innovative practices in mining

Learning intention

To understand how sustainability priorities have led to innovative practices in mining

Success criteria

SC 1: I can describe various innovative practices in mining.

SC 2: I can explain the influence of sustainability on mining practices.

Impacts of mining in Australia

The mining industry in Australia is a significant contributor to the country's economy, generating billions of dollars in revenue and providing jobs for thousands of people. However, mining operations can have a significant environmental and social impact.

Mining can damage the environment in various ways, including habitat destruction, overuse of freshwater resources (Figure 5.12.1), and pollution of air, land and waterways. These impacts can lead to long term environmental degradation and loss of biodiversity.

The mining industry is also heavily influenced by global supply and demand for resources. This can result in major fluctuations in commodity prices, which in turn affect profits, investment levels and job security in mining regions.

Mining can harm First Nations communities in many ways, including by damaging or limiting access to Country and cultural sites. For example, in May 2020, mining operations legally destroyed the Juukan Gorge rock shelters in Western Australia, which held sacred sites and evidence of over 46 000 years of continuous human occupation. These sites were deeply significant to the Puutu Kunti Kurrama and Pinikura peoples.

Mining companies in Australia are working to reduce a range of social and environmental issues by using more sustainable practices (Figure 5.12.2).



FIGURE 5.12.1 Water resources are used as part of dust reduction measures at an open cut mine.



FIGURE 5.12.2 Ongoing environmental monitoring is conducted following rehabilitation at a coal mine site.

Reducing impact

Sustainability in mining involves extracting resources in a way that minimises environmental and social harm while ensuring long-term resource availability. This can include using renewable energy to power mining operations or developing recycling methods to reduce the need for extracting raw materials from Earth.

KEY TERM

sustainability meeting the needs of the present without compromising the ability of future generations to meet their own needs



FIGURE 5.12.3 This solar farm provides energy to the coal mining town of Clermont in Queensland.



FIGURE 5.12.4 Water in mine tailings storage facilities is often recycled for further use in mineral processing.

Renewable energy

Many mining companies are exploring renewable energy options such as solar, wind and geothermal energy (heat from below Earth's surface) to reduce their dependence on fossil fuels and decrease their carbon emissions (Figure 5.12.3). In the past, mine sites relied on diesel fuel for energy, but diesel emits harmful carbon. Recently, the Agnew Gold Mine in Western Australia installed a 4 megawatt (MW) solar power station. Solar now provides around 50% of the mine's electricity needs and reduces the mine's carbon emissions by 9000 tonnes per year.

Water management

Mining companies are increasingly implementing water-saving measures and using recycled water instead of fresh water for mining activities (Figure 5.12.4). This reduces their water consumption and minimises their impact on local water resources. For example, the Olympic Dam copper–uranium mine in South Australia uses treated municipal wastewater for its operations, reducing the mine's freshwater use by up to 70%.

Waste reduction

Sustainable mining practices involve reducing the amount of waste generated by mining operations. One approach is to extract valuable minerals from mine waste sites. This involves reworking already mined rocks in tailings storage facilities and waste piles to extract more minerals. The result is less waste. For instance, the Ernest Henry copper–gold mine in Queensland uses a process called ore 'sorting' to separate waste rock from valuable mineral ores.

SCIENCE IN SOCIETY

Biomining

Biomining, also known as microbial mining or bioleaching, is an innovative practice that has the potential to reduce the environmental impact of mining.

In biomining, microbes such as bacteria, archaea and fungi extract metal from ores and minerals. This reduces the need for harmful chemicals, reduces waste and is more environmentally friendly.

Common metals that are being extracted by biomining include gold, copper, silver, cobalt and nickel.

Another exciting potential for biomining is the extraction of metals from 'urban mines'. Urban mining is the recovery of precious metals such as gold and copper from electronic objects (e-waste) (Figure 5.12.5).

Most e-waste ends up in landfill, contaminating soil, groundwater and waterways. Recovering metals from e-waste through biomining offers many environmental benefits.



FIGURE 5.12.5 Valuable metals can be recycled from e-waste through urban mining.

Social sustainability

Sustainability in mining includes social outcomes to support local communities and promote social development. While mining can have significant negative impacts on First Nations communities, there are growing efforts to address these issues. Many mining companies are working with First Nations communities to try to improve social outcomes, create employment opportunities and offer training and education programs. For example, the Gumatj Corporation, an Indigenous owned organisation in the Northern Territory, partnered with a mining company to create the Gulkula Mining Training Centre, providing training and job pathways for local people. Today, the Gumatj Corporation owns and operates its own bauxite mine, giving them greater control over how the social outcomes of this mine are managed.

SC 1 CHECK YOUR UNDERSTANDING

Identify one innovative practice in mining that promotes sustainability.

SC 2 I can explain the influence of sustainability on mining practices

Importance of sustainability

Sustainability has become increasingly important in the mining industry in Australia in recent years. Demand for minerals and resources continues to grow, which leads to additional challenges. Mining companies are recognising that they need to change how they operate so that they can continue operating in the long run.

Awareness of the environmental impact

There has been a growing awareness of the environmental impact of mining, particularly in relation to carbon emissions, water use and waste generation (Figure 5.12.6). This has led to increased pressure on mining companies to reduce their environmental impact and adopt more sustainable practices, including the rehabilitation of mine sites back to what they were, and the reduced use of harmful chemicals.

Shift in public perception

There has been a shift in public perception of the mining industry. A greater emphasis has been placed on social responsibility and the importance of supporting local communities. This has increased the checking and regulation of mining practices, and mining companies have recognised the need to build strong relationships with local communities (Figure 5.12.7).



FIGURE 5.12.6 The tailings storage of fluids used in the processing of titanium ore must be managed carefully to prevent environmental impact.



FIGURE 5.12.7 Ranger Mine in the Northern Territory works closely with First Nations Peoples and the residents of the nearby town of Jabiru.



FIGURE 5.12.8 A wind farm powering Garzweiler (a German open cut coal mine) is built on previously mined land that has been rehabilitated and returned to agriculture.

Technological advances

Finally, there have been technological advances that have made sustainable mining practices more feasible and cost-effective. For example, the use of renewable energy sources such as solar and wind power has become more cost-competitive (Figure 5.12.8). Technologies for water treatment and waste reduction have also improved. Biomining offers the potential to extract further resources through the recycling of waste.

Overall, adopting sustainable practices means mining companies can ensure that they operate in a way that is environmentally responsible, socially beneficial and economically viable in the long run.

SC 2 CHECK YOUR UNDERSTANDING

Describe how a mining company might reduce its environmental impact through sustainable practices.

Lesson review

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

1. Identify the three aspects that must be considered by mining operations to effectively work towards being sustainable.
2. Describe two innovative practices in mining that consider environmental issues, and outline how they promote sustainability.
3. Outline how a mining company might implement water recycling in its operations to enhance sustainability.
4. Gumatj Mining in the Northern Territory is owned and operated by Yolngu, the First Nations People of north-east Arnhem Land. Give two reasons why a mining company such as Gumatj can achieve social sustainability.
5. Compare the environmental and social impacts of mining. How are they different and how might they overlap?
6. A Queensland mine site was once one of the largest gold mines in the world, but gold production ceased there many years ago. There are now plans to re-open the mine to re-work thousands of tonnes of tailings and waste piles.
   a. Name one innovative practice that could result in the extraction of more gold from the waste.
   b. Suggest how energy might be provided sustainably to this venture.
   c. The population of the nearby town has declined since the closure of the mine, with many people now unemployed. Explain how re-opening the mine could benefit the community.

5 The rock cycle

Topic summary

The key concepts included in this topic are:

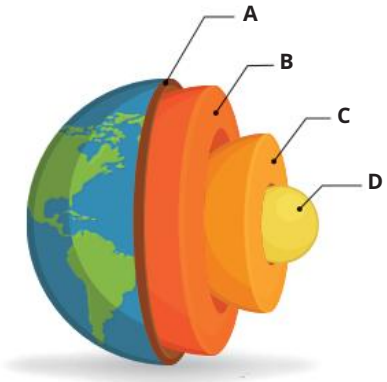
- Earth's internal structure is made up of four main layers.
- Rocks on the surface of Earth undergo constant change.
- Weathering of rocks can be physical (mechanical), chemical and biological.
- Sedimentary rocks form when rocks are weathered, eroded and deposited as sediments, with the sediments then undergoing the geological processes of compaction and cementation.
- Resources in rocks can be identified by using deep Earth imaging techniques.
- Intrusive igneous rocks form when rocks melt to form magma and then solidify below Earth's surface. Extrusive rocks form when lava solidifies on Earth's surface.
- Metamorphic rocks form when rocks are exposed to high heat and/or pressure.
- Environmental changes affect the processes and rock types in the rock cycle.
- The mining of Australian mineral resources influences and affects society, with societal expectations in return influencing the mining industry.
- Mining in Australia can have economic and environmental impacts.
- Innovative practices in mining have been developed in response to sustainability priorities.

Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

Remember

1 Use the diagram of the layers of Earth to complete the following questions.



- **a** Identify the layers of Earth shown on the diagram.
- **b** Which layer is liquid?
- **c** How do scientists know about the composition of Earth's internal layers?

2 Compare the processes of erosion and deposition.

3 Identify the common features of sedimentary rocks.

4 First Nations Peoples in Australia have been long involved in the extraction of mineral resources. State one example that outlines where mineral extraction occurs or has occurred, and the First Nations Peoples who value the resource.

Understand

5 Describe the difference between the lithosphere and the asthenosphere.

6 A dichotomous key is a useful tool to classify rocks.

- **a** Describe the features of a dichotomous key.
- **b** State the characteristics that would help you to distinguish an intrusive igneous rock from a clastic sedimentary rock while using a dichotomous key.

7 If a granite rock is exposed to acid rain, which type of weathering will occur, and what will be the result?

8 Describe the three types of metamorphism that transform parent rocks into metamorphic rocks.

Apply

9 Deep Earth imaging has found a possible coal deposit. The mining company needs to consider if mining the resource could be profitable.

- **a** Name one deep Earth imaging technique that could have been used to locate this resource below the ground.
- **b** State two reasons why waste will be part of the mining company's considerations.
- **c** Outline three practices the mining company could adopt to align with sustainability goals.

10 Australia has a very extensive coastline with a variety of landforms.

- **a** Name three landforms you might see on the coast.
- **b** List two environmental factors that contribute to the weathering of rocks in a coastal area.
- **c** Explain how weathering and erosion work together to shape the coastal landscape.

11 In August 2019 a volcano erupted under the surface of the Pacific Ocean near Tonga. The only sign of the undersea eruption was a large 150 square kilometre raft of bubbly igneous pumice floating on the ocean surface.



- **a** What type of igneous rock is pumice?
- **b** Explain the processes of igneous rock formation that results in a raft of pumice on the ocean surface.
- **c** Lots of pumice ended up on the east Australian coastline after some months. It was covered in algae, barnacles, corals and worms. Propose why the pumice rocks had become much smaller in this time.
- **d** Name the stage in the rock cycle reached by the pumice once it arrived on Australia's beaches.

12 Consider a crystal of quartz. Draw a rock cycle diagram to show the geological processes required for quartz to form:

- the extrusive igneous rock rhyolite, then
- the sedimentary rock sandstone, then
- metamorphic quartzite.

Analyse

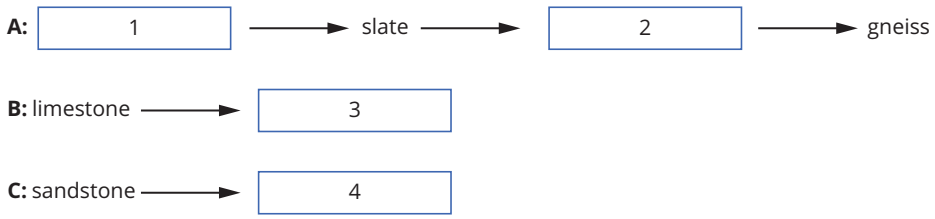
13 A species of marine trilobite has been discovered for the first time in sedimentary rock in the Sahara Desert in Algeria.

- **a** Describe the sedimentary rock's formation environment.
- **b** Outline the geological processes that would bring the trilobite fossil from the environment of its formation to the sands of the Sahara Desert.
- **c** Assess the usefulness of this species of trilobite as an index fossil.

14 You have found this igneous rock. It is about 4 cm wide. What can you infer about its formation?



15 You have been given a number of metamorphic rocks that have been organised into three metamorphic sequences (A, B and C). Some of the rock's labels are missing.



a Identify the unlabelled rocks numbered 1–4 that belong to the metamorphic sequences.
b Identify the parent rock in each sequence.
c Describe a feature you would expect gneiss to have that Rock 1 would not have.

Extension: Research task

16 'Diamonds are formed from the metamorphism of coal.'

Conduct research to evaluate the validity of this statement. In your research, determine how diamonds at or near Earth's surface are formed. Is coal involved in this process, and if so, how?

Present a short report of 200–300 words outlining the diamond formation processes. Conclude your report with an evaluation of the validity of the statement.

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

asthenosphere the layer of Earth near the top of the mantle, just below the solid lithosphere, and containing rock that can move very slowly

biogenic sedimentary rock sedimentary rock formed mainly from dead organisms

biological weathering living things and their products breaking down rock

cementation the binding together of sediments as part of the formation of sedimentary rock

chemical sedimentary rock sedimentary rock formed when dissolved materials precipitate from solution

chemical weathering water dissolving chemicals in minerals or air, resulting in the breaking down of rocks

clastic sedimentary rock sedimentary rock formed mainly from small rock particles

compaction the squeezing of layers of sediments caused by pressure from layers above

contact metamorphism a type of metamorphism where rock is altered mostly by heat

crust the outermost layer of Earth, composed of solid rock

crystallisation evaporation of a solvent from a solution, leaving solute behind as crystals

deposited the settling of broken rock material to form sediment

dichotomous key a key with two choices at each stage

dynamic metamorphism a type of metamorphism where rock is altered mostly by pressure

erosion the movement of weathered rock particles from the site of the weathering

extrusive igneous rock igneous rock that forms on the surface of Earth

foliated a process where minerals under pressure realign and the rock develops layers or bands

fossil the preserved remains of a once-living organism

geothermal energy the heat energy that comes from within Earth

humus dark material in soils produced by the decomposition of plant or animal remains

igneous rock rock formed by the cooling of molten rock, e.g. basalt

index fossil a fossil that can be used to compare the relative age of rock strata in different locations

inner core extremely hot, solid ball made of iron and nickel at the very centre of Earth

intrusive igneous rock igneous rock that forms below the surface of Earth

lava molten rock that reaches Earth's surface

lithosphere the crust and the upper mantle together; Earth's tectonic plates

magma molten rock below Earth's surface

mantle the solid layer of Earth between the crust and the outer core

metamorphic rock rock formed when heat and/or pressure alter existing rock

mineral a naturally occurring solid substance that is inorganic, has a characteristic crystalline structure and a fairly constant chemical composition

outer core a liquid layer of Earth's interior, primarily composed of liquid iron and nickel; located beneath the solid mantle and surrounds the inner core

parent rock a rock that experiences metamorphism, or changes form, to become a new kind of rock

physical weathering the breaking down of rocks by physical processes

porphyritic the texture of intrusive and extrusive igneous rocks that have large crystals surrounded by finer crystals or grains

primordial something that originated during the planet's formation process a very long time ago

regional metamorphism a type of metamorphism where rock is altered by both heat and pressure over a wide area

rock a solid mass of one or more minerals

rock cycle a model geologists use to explain the endless cycle of change that rocks undergo

sediment solid material that has broken down and moved because of erosion

sedimentary rock rock made by sediments being compacted and cemented together

spit a stretch of beach material, connected to land and jutting out into the water

sustainability meeting the needs of the present without compromising the ability of future generations to meet their own needs

volcano a place where extremely hot material from inside Earth erupts at the surface

weathering the physical, chemical and biological processes that break down rocks into smaller pieces



TOPIC 6

Theory of plate tectonics

Volcanic eruptions and earthquakes are a result of motions both within and on Earth's surface. During a volcanic eruption, magma from within Earth erupts onto its surface. Earthquakes occur as a result of built-up stress and energy due to movements of Earth's crust.

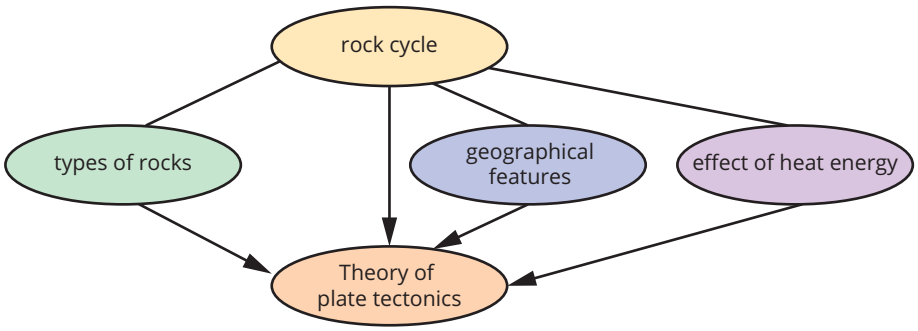
In this topic, you will learn about the theory of plate tectonics and explore how pressures and movements in Earth's crust affect both the geological features and living organisms on Earth's surface.

Learning intentions

- ☐ To understand the reasons for patterns of earthquake and volcanic activity around the globe **271**
- ☐ To understand the theory of plate tectonics **279**
- ☐ To be able to explain how rock in the mantle moves **285**
- ☐ To understand geographic evidence that supports the theory of plate tectonics **287**
- ☐ To be able to create a model that demonstrates the formation of magnetic striping as evidence for the theory of plate tectonics **294**
- ☐ To be able to develop investigable questions that can be answered using a model that represents the theory of plate tectonics **297**
- ☐ To understand biological evidence that supports the theory of plate tectonics **301**
- ☐ To understand the physical phenomena that occur at the different types of plate boundaries **306**
- ☐ To be able to model the different types of plate boundaries **311**
- ☐ To be able to develop and test a hypothesis to explore scientific models **314**
- ☐ To be able to explore how cultural building techniques led to the development of structures and materials better able to withstand the effects of earthquakes **317**
- ☐ To understand how seismic data is collected and shared between governments across the Asia–Pacific region to produce tsunami alerts **319**

6 Theory of plate tectonics

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.

Types of rocks

1 Earth is made up of four distinct layers.

- **a** Name the four layers of Earth.
- **b** State which is the only liquid layer.
- **c** Identify the layers that make up the lithosphere.

2 Identify the three types of rocks.

Rock cycle

3 Outline the processes that form sedimentary rocks.

4 Compare the formation of intrusive and extrusive igneous rocks.

5 Describe how an igneous rock becomes a metamorphic rock.

Geographical features

6 Identify three hazards that are created by geological activity in Earth's crust.

7 Explain why marine fossils are found in the Himalayas.

6.1 Earthquake and volcanic activity

Lesson overview

Volcanic eruptions and earthquakes can cause a great deal of destruction. By understanding the processes involved when an earthquake occurs and a volcano erupts, scientists and engineers can better prepare people for a possible disaster.

In this lesson, you will learn about the locations of earthquakes and active volcanoes (Figure 6.1.1) and how scientists measure the magnitude of an earthquake.



FIGURE 6.1.1 The active volcanoes of Bromo, Batok and Semeru are located on the island of Java in Indonesia.

SC 1 I can analyse live data to identify areas of volcanoes and earthquakes in the Asia–Pacific region

Learning intention

To understand the reasons for patterns of earthquake and volcanic activity around the globe

Success criteria

SC 1: I can analyse live data to identify areas of volcanoes and earthquakes in the Asia–Pacific region.

SC 2: I can describe patterns in the locations of earthquakes and volcanoes.

SC 3: I can describe how the magnitude of earthquakes is measured.

Earthquakes

Earthquakes are sudden movements in Earth's crust. Some are weak and can only be detected by sensitive instruments, called **seismometers**. Some can cause significant damage.

Volcanoes

A **volcano** is formed where there is a gap in Earth's crust. This allows lava, ash and gases to escape from below the surface, often forced out by extreme pressures.

KEY TERMS

earthquake the rapid movement of the ground, usually back and forth and up and down in a wave motion, due to the movement of tectonic plates

seismometer an instrument that detects the seismic waves from an earthquake

volcano a place where extremely hot material from inside Earth erupts at the surface

Scifile

Volcano lightning

During eruptions from the more explosive composite volcanoes, lightning can often be seen in the ash plume or ash cloud. This happens because the ash particles create static electricity, similar to how thunderclouds produce lightning. During the eruption of Washington's Mt St Helens volcano in 1980, bolts of lightning struck the ground, sheet lightning lit up the ash plume, and very rare ball lightning was also observed.

Volcanoes and earthquakes around the world

Figures 6.1.2 and 6.1.3 show data of earthquakes and volcanoes around the world. Notice some of the similarities between these two maps.

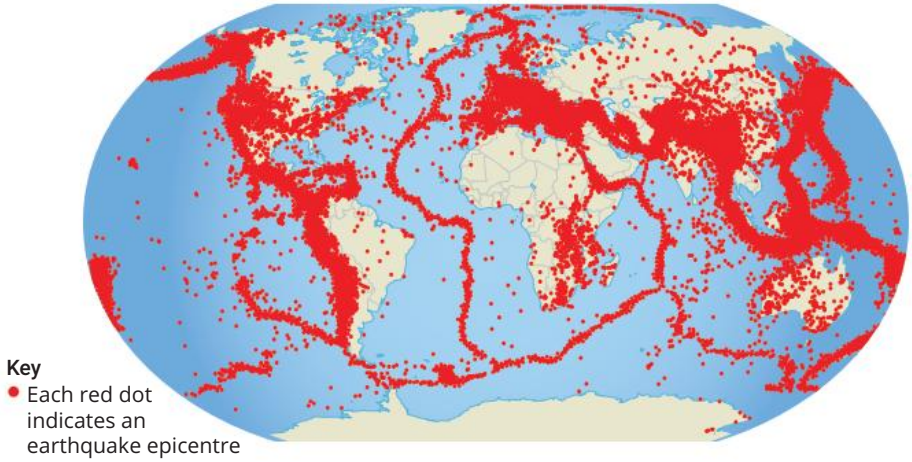


FIGURE 6.1.2 Distribution of earthquakes around the world



FIGURE 6.1.3 Distribution of active volcanoes around the world

Collecting and viewing live seismic data

Earthquakes and erupting volcanoes can cause a lot of damage and destruction to life on Earth. Government organisations such as Geoscience Australia and United States Geological Survey (USGS) constantly monitor earthquake and volcanic activity. Earthquakes and volcanic activity are recorded by a network of **seismographs**. The **seismic data** is then used to predict potential follow-up earthquakes (aftershocks) and the likelihood of volcanic eruptions. Countries use the live data to plan for evacuations and other disaster preparations.

The seismic data collected at seismic stations is made available as live data. The public (including you) can view the live data. Interactive earthquake and volcano maps can be accessed on websites such as Geoscience Australia Earthquakes, USGS Latest Earthquakes, and ArcGIS Online Live Earthquakes and World Volcanoes. These maps regularly update with live data.

KEY TERMS

seismograph a seismometer that is connected to a recording device

seismic data data about movements of the ground that is used by scientists to study and monitor earthquakes

A range of tools on the websites assist exploration of seismic events, including the location of tectonic plate boundaries, indicators of earthquake strength, and volcano types and current volcanic activity.

Patterns in the data

Active volcanoes and earthquakes do not usually occur all over the surface of Earth. The live seismic data shows that volcanoes and earthquakes more commonly occur together in concentrated areas along **tectonic plate** boundaries. In the Asia–Pacific region, these areas are concentrated around Indonesia, Philippines, Japan and New Zealand. This is where the Australian, Philippine (also known as Philippine Sea), Eurasian and Pacific Plates interact.

KEY TERM

tectonic plate a section of Earth's lithosphere that moves about on Earth's surface

SC 1 CHECK YOUR UNDERSTANDING

Explain why live data is crucial for identifying and responding to volcanic and earthquake activity.

SC 2 I can describe patterns in the locations of earthquakes and volcanoes

Tectonic plates

Earth is made up of different layers of material. The outermost layer is broken up into large pieces known as tectonic plates.

The tectonic plates can move across the surface of Earth. This is a very slow process. On average, the plates only move about 1.5 cm per year!

It is generally accepted among scientists that there are seven large tectonic plates. There are also several smaller plates across the surface of Earth (Figure 6.1.4). The scientific theory that describes the existence and motion of these plates is the theory of plate tectonics.

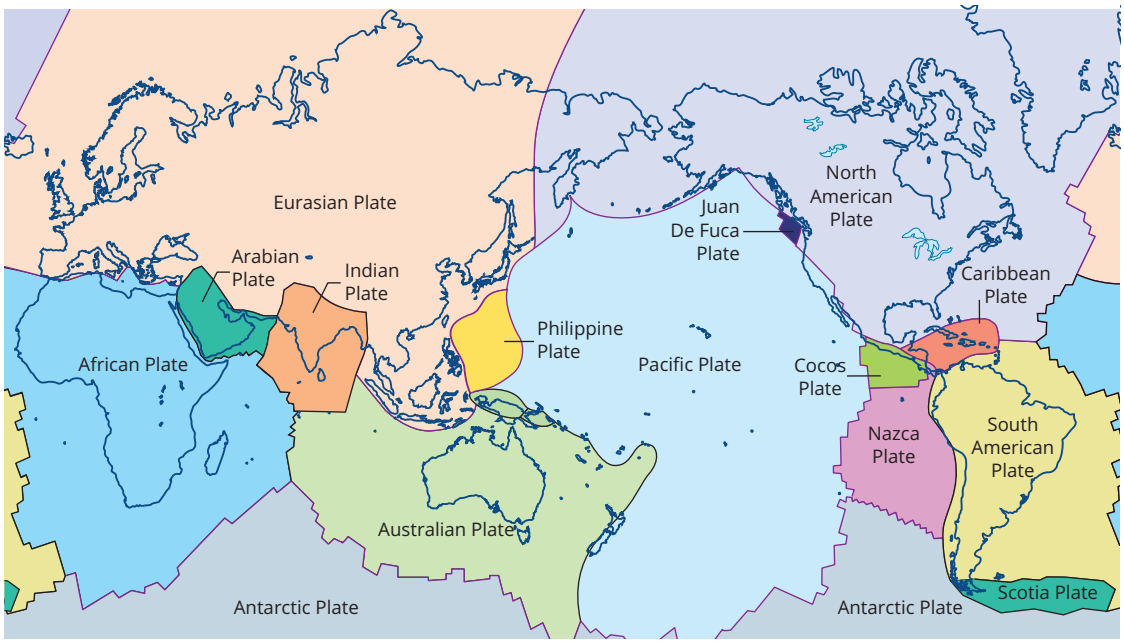


FIGURE 6.1.4 The surface of Earth is broken up into major and minor tectonic plates.

The areas where two plates meet coincide with the areas where the greatest number of active volcanoes and earthquakes occur. The interaction of the tectonic plates generally causes both natural events to occur.

Not all earthquakes and volcanoes occur on these boundaries though.

Hot spot volcanoes

KEY TERM

hot spot an isolated place away from plate boundaries where a lot of hot magma collects

Sometimes volcanoes are formed far away from a plate boundary. These are known as **hot spot** volcanoes (Figure 6.1.5). A hot spot is an area where super-hot material rises from inside Earth. The hot spot does not move.

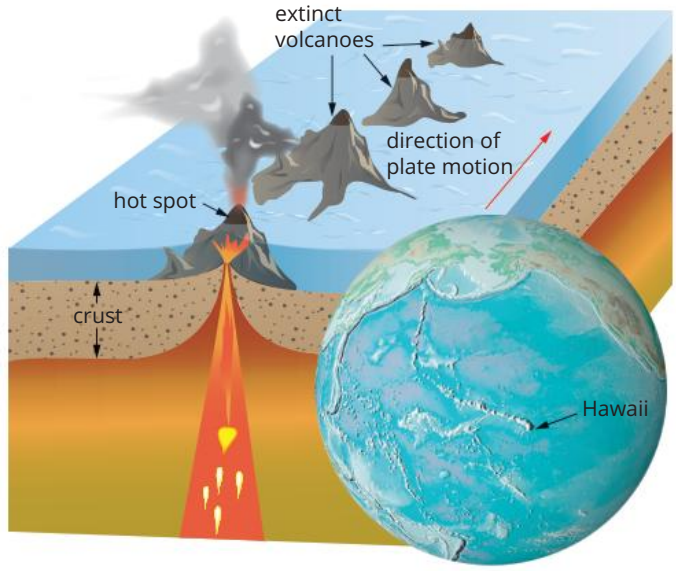


FIGURE 6.1.5 Volcanoes are formed as a tectonic plate moves across a hot spot.

As a tectonic plate moves over a hot spot area, a volcano can form. As the plate continues to move, a chain of island volcanoes is created. The volcanoes become first dormant and then extinct as they move away from the hot spot. This phenomenon can be seen in Hawai'i, where a chain of extinct and active volcanoes has been formed as the plate moves over the hot spot.

DISCOVER MORE

When a volcano no longer has a magma supply and it is unlikely to erupt in the future, it is considered extinct. Volcanoes that have not erupted for a long time but may erupt in the future are called dormant (or inactive). Active volcanoes show signs of activity and may erupt soon.

Intraplate earthquakes

KEY TERMS

intraplate earthquake an earthquake that occurs away from a plate boundary
lithosphere the crust and the upper mantle together; Earth's tectonic plates
magma molten rock that does not reach Earth's surface

An earthquake that occurs away from a plate boundary is called an **intraplate earthquake**. Intraplate earthquakes happen when movement along pre-existing faults or fractures relieves the build-up of strain in the **lithosphere**. Movement of **magma** beneath the surface can also trigger intraplate earthquakes. Smaller faults can also form within the plate as it bends during interactions with another plate.

SC 2 CHECK YOUR UNDERSTANDING

Compare the location of hot spot volcanoes and the location of most of Earth's active volcanoes.

SC 3 I can describe how the magnitude of earthquakes is measured

When an earthquake causes the ground to shake, it transfers energy from the interaction between the plate boundaries into the back-and-forth, up-and-down or side-to-side wavelike motion of the ground. These waves are called **seismic waves**. The waves travel outwards from the point where the earthquake occurred underground. This point is called the **focus**. The focus can be anywhere from deep underground to close to the surface.

The **epicentre** of an earthquake is the point on the surface of Earth directly above the focus (Figure 6.1.6).

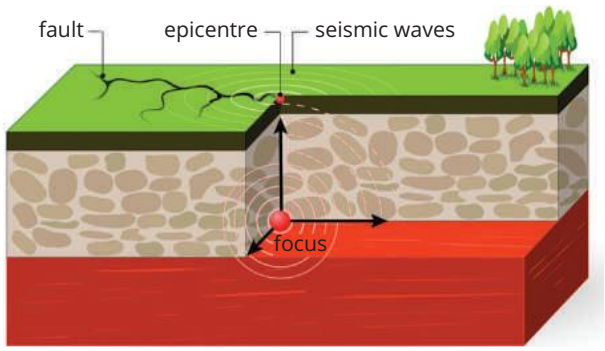


FIGURE 6.1.6 The location of an earthquake's focus and epicentre

KEY TERMS

seismic wave the shaking, wave-like movement of the ground in an earthquake
focus the place below ground where an earthquake starts
epicentre the point on Earth's surface directly above the focus of an earthquake
seismogram the recorded information from a seismograph

There are three types of waves involved in an earthquake: primary, secondary and surface.

- Primary waves (P-waves) travel the fastest and can travel through solids, liquids and gases.
- Secondary waves (S-waves) are slower than P-waves and can only travel through solids.
- Surface waves only travel along the surface of Earth and can cause the most damage. They are also the slowest of the three waves.

Detecting earthquakes

Scientists invented instruments called seismometers, which can detect when an earthquake is occurring. The full device is called a seismograph when it is connected to a recording device (Figure 6.1.7). A heavy mass resists the motion of the earthquake while the rest of the instrument is caused to shake. The motion of the weight is then recorded as a **seismogram** (Figure 6.1.8). Seismograms may be recorded on paper or recorded digitally.

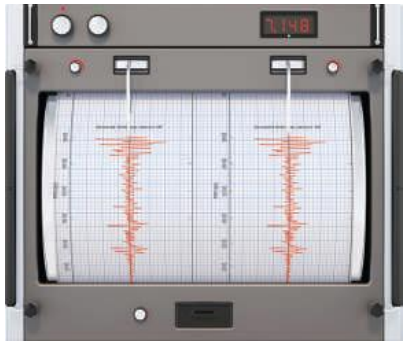


FIGURE 6.1.7 A seismograph detects, measures and records seismic vibrations.

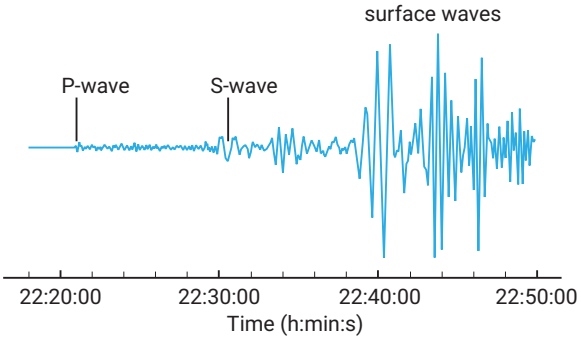


FIGURE 6.1.8 A seismogram records seismic vibrations, including the different arrival times of P-waves, S-waves and surface waves.

KEY TERMS

magnitude a measure of the size or strength of something
intensity a measure of the effect of something

Comparing earthquakes

Different scales are used to compare earthquakes. These are **magnitude** and **intensity** scales.

Magnitude

The magnitude of an earthquake describes the amount of energy that is transferred by the seismic waves. It is usually measured using the moment magnitude (M_W) scale. The magnitude in this scale is calculated using the size of the waves measured by the seismograph and the distance to the epicentre.

The minimum value on the moment magnitude scale is 1. It is a logarithmic scale, which means that each value is 10 times greater than the previous number. There is technically no upper limit to the moment magnitude scale, but due to the geology of Earth, an earthquake equal to or greater than 10 is not possible.

SCIENCE IN SOCIETY

Richter scale and moment magnitude scale

The Richter scale was originally devised to measure the magnitude of earthquakes in southern California in the United States. Charles Richter and Beno Gutenberg were the first to use a logarithmic scale for measuring the size of earthquakes. The data used was from local seismograph stations, so the Richter scale was referred to as M_L (L for local). The Richter scale worked well for the California situation with earthquakes of between magnitude 3 and 7, but as its use spread around the world, it was found that it became quite inaccurate for higher magnitude earthquakes.

New magnitude scales were developed based on the Richter scale: M_B used body wave magnitude data, and M_S used surface wave magnitude. Again, these scales did not work for all magnitude earthquakes. For earthquakes measuring magnitude 6.5 or greater, these scales were unreliable.

The moment magnitude scale (M_W) was developed in the late 1970s by Hiroo Kanamori (a Japanese seismologist) and US seismologist Thomas Hanks. For very large earthquakes, moment magnitude scale is currently the most reliable.

Earthquake magnitudes using the Richter scale are still reported by media, sometimes in error as the moment magnitude scale is the actual scale used. However, in the initial stages of measuring an earthquake's magnitude, the Richter scale may be used as a guide, with amendments made to the magnitude after further M_W calculations are completed.

So next time you hear the news that 'an earthquake of 8.2 on the Richter scale has occurred', wait a little while for the more accurate moment magnitude value to be assigned. As an example, the Great Tohoku Earthquake in Japan has been classified as a magnitude (M_W) 9.0–9.1 earthquake. Initial reports stated it was 7.9.

As more is learnt about earthquakes and the behaviour of seismic waves, further adjustments may be made to the way magnitude is calculated.

Intensity

The intensity of an earthquake is measured by its effects on people and structures. Intensity is measured on the modified Mercalli intensity (MMI) scale and is calculated using observations by people.

Figure 6.1.9 shows the modified Mercalli intensity scale and the moment magnitude scale. It also shows the numbers of earthquakes of different intensities and scales per year, with some examples of higher intensity and magnitude earthquakes.

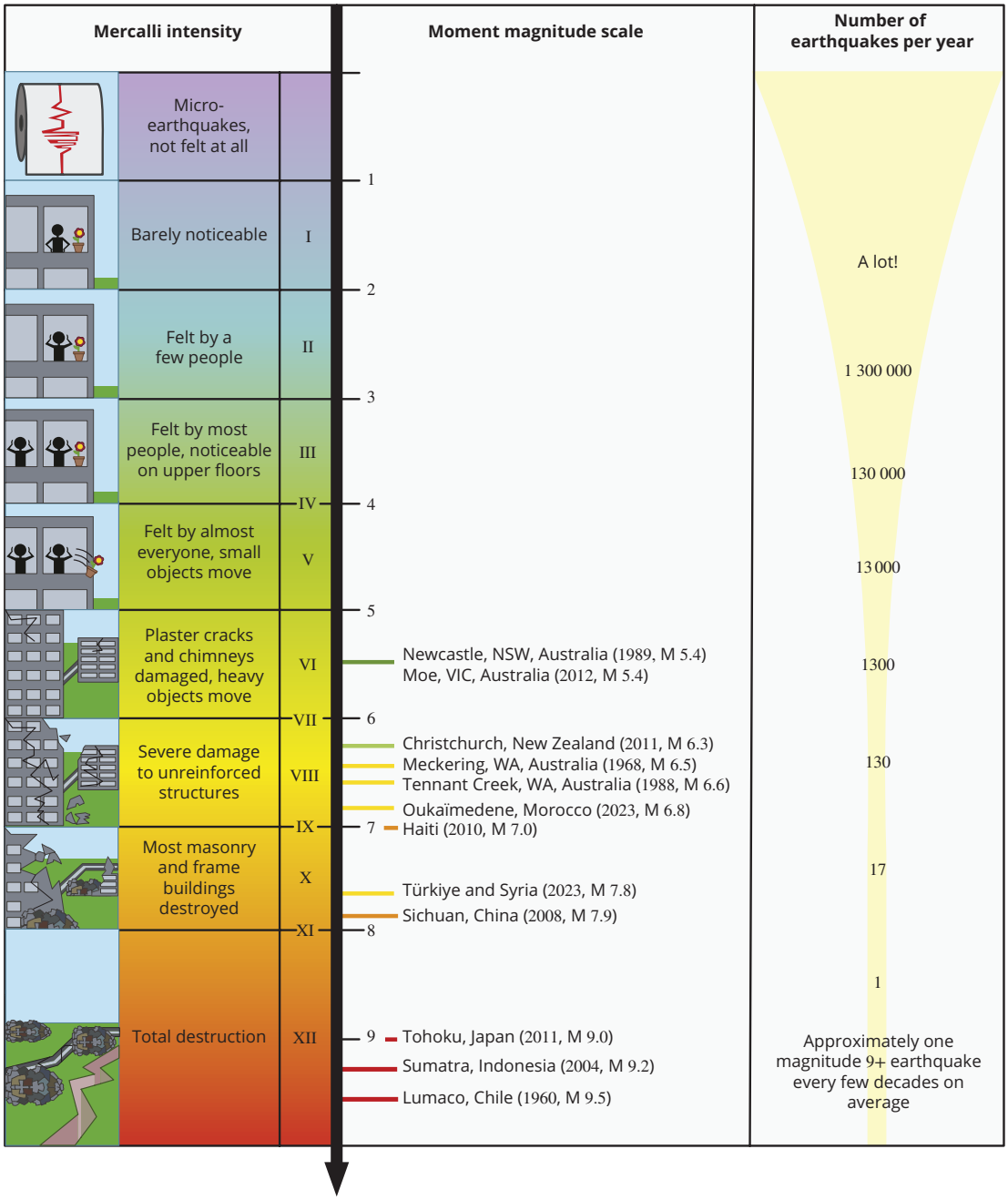


FIGURE 6.1.9 Comparison of the modified Mercalli intensity (MMI) scale and the moment magnitude (M_W) scale, the frequency of earthquakes and some examples of earthquakes

SC 3 CHECK YOUR UNDERSTANDING

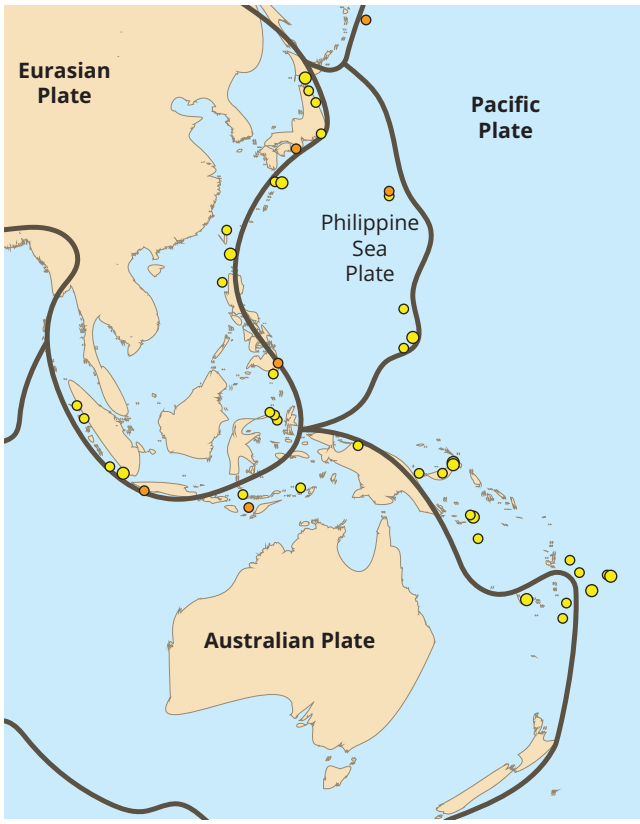
Explain how the magnitude of an earthquake is calculated.

Lesson review

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

1 Explain why the Asia–Pacific region is prone to earthquakes and volcanic activity.

2 Refer to the image below which shows the occurrence of magnitude 4.5+ earthquakes in the Asia–Pacific region over a seven-day period.



a Describe the distribution of earthquakes.
b Explain why the earthquakes are located where they are.
c Name the tectonic plates that are interacting in this section of the Asia–Pacific region.
d Identify a natural feature you could expect to see where earthquakes occur.

3 The Galapagos Islands are a series of volcanic islands in the Pacific Ocean. Many of the volcanoes are now extinct, but Isabela Island and Fernandina Island have several active volcanoes. The Galapagos Islands are located on the Nazca Plate at some distance from the plate's boundaries. Explain why these islands would be forming here.

4 Identify the type of seismic wave that has the following features.
a can only travel through solids and are slower than the waves that can travel through solids, liquids and gases
b can only travel along Earth's surface, but despite being the slowest of the seismic waves they can do the most damage
c travel the fastest and can travel through solids, liquids and gases

5 Compare the moment magnitude scale and modified Mercalli intensity scale as methods for measuring earthquakes.

6 A magnitude 4.5 earthquake has occurred in Indonesia. Citizen scientists recorded the following data.

Location	Modified Mercalli intensity (MMI)	Distance from epicentre (km)
1	VII	10
2	II	135
3	III	97

a Identify the location that experienced more intense effects of the earthquake. Explain why you selected this location.
b Explain why the MMI results vary for the three locations.

6.2 The theory of plate tectonics

Lesson overview

The tectonic plate theory says that the surface of Earth is divided into large segments (Figure 6.2.1). Due to the geology of Earth, these segments can move across the surface—pushing and pulling against each other. This theory was developed in the early 1900s, and today there is much evidence to support it.

In this lesson, you will learn about the theory of plate tectonics, how plates are able to move, and what impact these motions have on Earth.

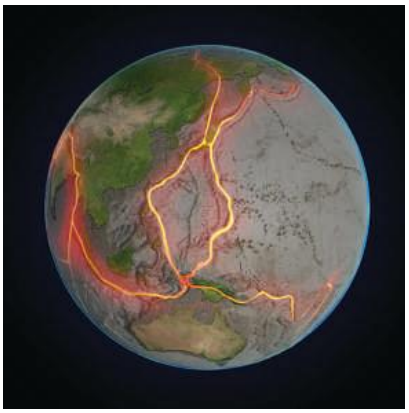


FIGURE 6.2.1 Tectonic plate boundaries in the Asia-Pacific region

Learning intention

To understand the theory of plate tectonics

Success criteria

SC 1: I can describe the layers of Earth and how they were formed.

SC 2: I can identify the tectonic plates.

SC 3: I can explain the forces of motion of tectonic plates.

SC 1 I can describe the layers of Earth and how they were formed

A very, very long time ago (4.5 billion years), Earth was formed from collisions between gas and dust, which clumped together under gravity.

Initially, Earth was an extremely hot molten ball of elements. Due to gravitational forces, the heavy materials, such as iron and nickel, fell to the centre of Earth, leaving the lighter materials near the surface. Eventually, this process created different layers within Earth, each of which have different properties.

These layers include the core, the mantle and the crust. The crust and the top layer of the mantle form a hard, brittle layer called the lithosphere (Figure 6.2.2). At some point during the formation of Earth, the lithosphere fractured into pieces, called tectonic plates.

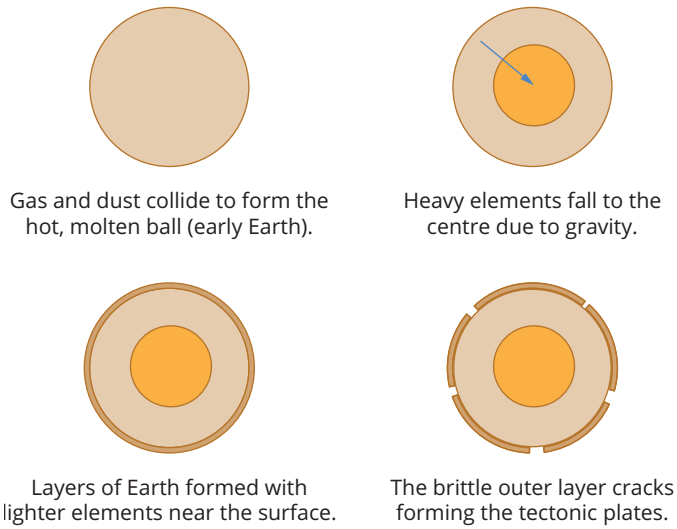


FIGURE 6.2.2 Stages in the formation of Earth's layers and the tectonic plates

Structure of Earth

Each layer of Earth has different properties (Figure 6.2.3).

- Lithosphere—The solid lithosphere is the outermost layer of Earth, which consists of the topmost rigid part of the mantle along with the crust. The lithosphere makes up the tectonic plates.
- Asthenosphere—The **asthenosphere** is described as plastic because, despite being made up of solid rock, it can bend and flow over very long time scales. The asthenosphere is around 600 km thick.
- Lower mantle—A solid layer between the core and the asthenosphere, which is around 2100 km thick.
- Outer core—A liquid outer core composed of iron and nickel, estimated to be around 2200 km thick.
- Inner core—A solid, inner core composed of iron and nickel, estimated to be around 2400 km in diameter.

KEY TERMS

asthenosphere the layer of Earth near the top of the mantle, just below the solid lithosphere, and containing rock that can move very slowly
oceanic crust the crust that forms the ocean floor
continental crust the crust that forms the continents

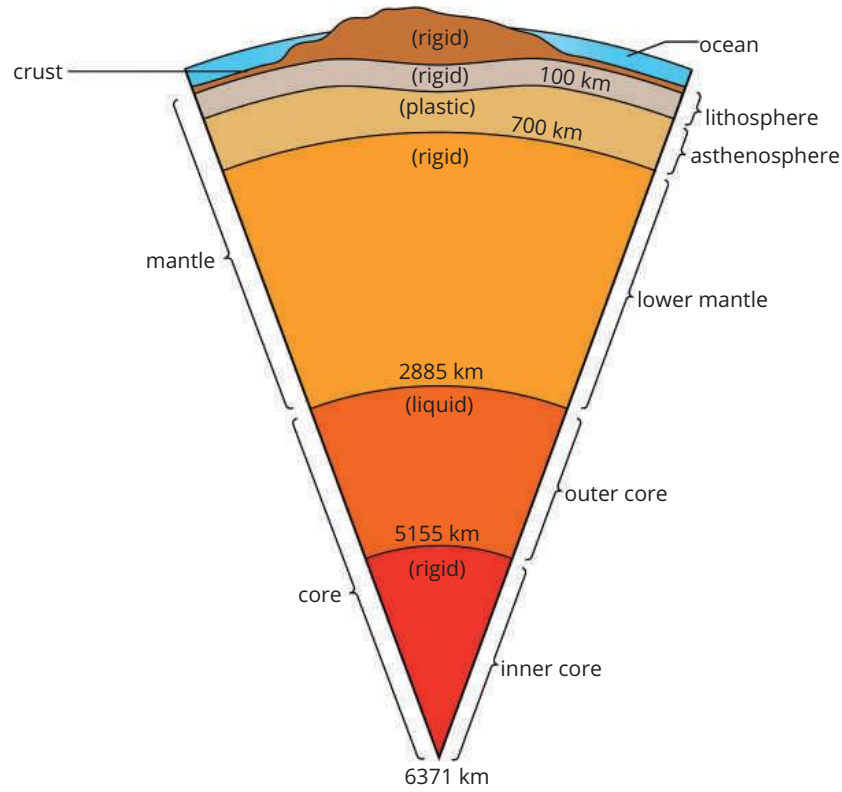


FIGURE 6.2.3 Properties of the layers of Earth

Continental or oceanic crust

The lithosphere's outer crust layer exists as two different types: oceanic and continental.

Oceanic crust is located on the ocean floor, and **continental crust** is located where there are continents.

Oceanic crust is generally denser than continental crust.

SC 1 CHECK YOUR UNDERSTANDING

Compare the properties of the lithosphere and the asthenosphere.

SC 2 I can identify the tectonic plates

In 1912, Alfred Wegener proposed a theory that the continents were drifting across the surface of Earth and that they once had all been joined together in one super continent. Wegener called this large landmass Pangaea, meaning 'all Earth' (Figure 6.2.4).



FIGURE 6.2.4 Earth's continents are thought to have once been joined together in a supercontinent called Pangaea.

This theory was called continental drift, and at the time that Wegener proposed it, it was highly contested. Today, the **theory of plate tectonics**, which now describes how this motion can occur, is generally accepted by the scientific community.

KEY TERM

theory of plate tectonics the scientific theory that describes the existence and motion of tectonic plates

There are around seven major tectonic plates on Earth. The massive solid plates are constantly in motion over very long time scales. Each year, the tectonic plates move (on average) 1.5 cm. This is not a big difference over a few years, but over geological time scales of millions of years, this movement causes some big changes to the structure of Earth's surface.

The major tectonic plates are the African, Antarctic, Eurasian, North American, South American, Australian and the Pacific Plates. These are called major plates because they each have an area greater than 20 million square kilometres. The smaller plates are called minor plates. The minor plates include the Arabian, Caribbean, Cocos, Indian, Juan De Fuca, Nazca, Philippine (also known as Philippine Sea) and Scotia Plates (Figure 6.2.5).

There is still some debate about the classification of plates. For example, some scientists group the minor Indian Plate and the major Australian Plate together to create the major Indo-Australian Plate. Others recognise sections of the lithosphere as separate plates; for example, the Anatolian Plate beneath Türkiye as separate to the Eurasian Plate.

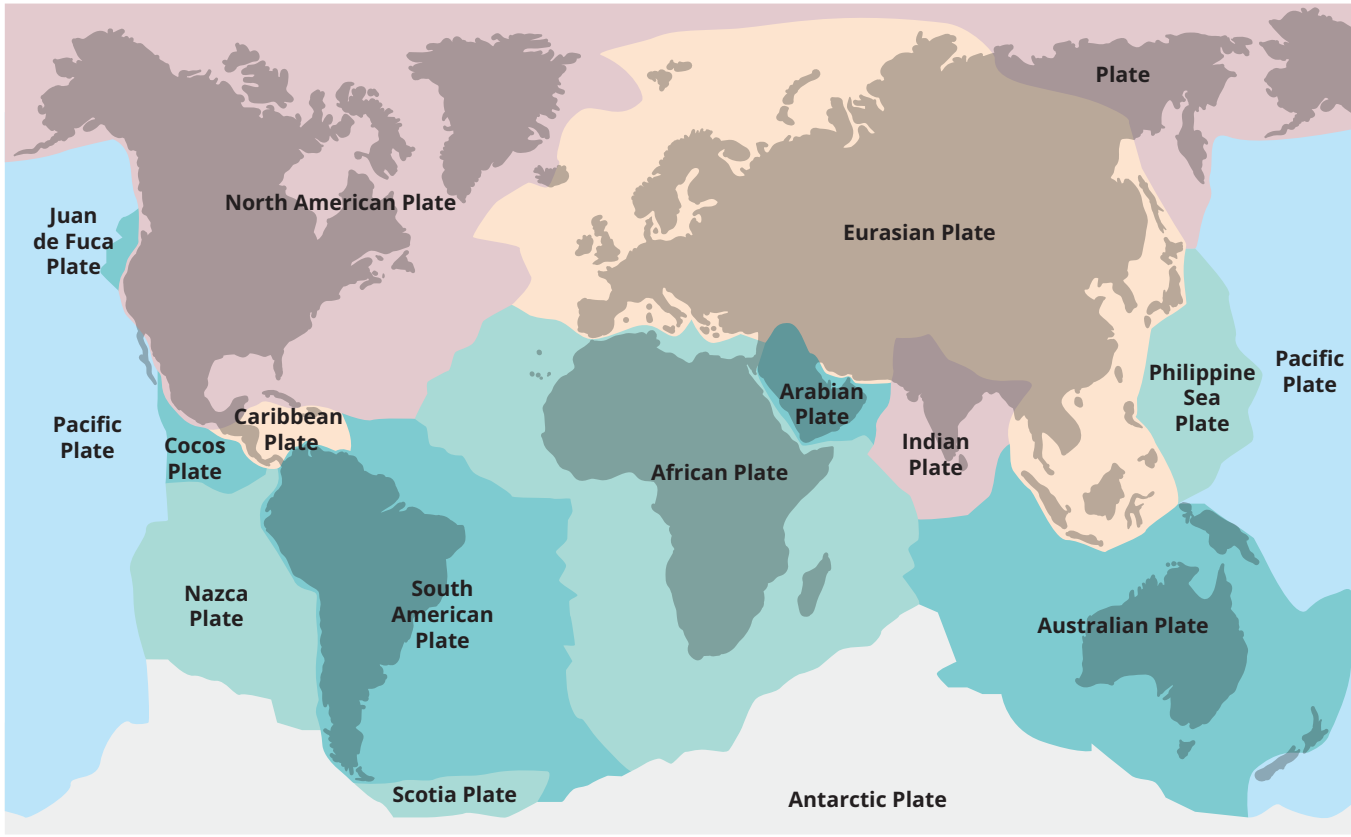
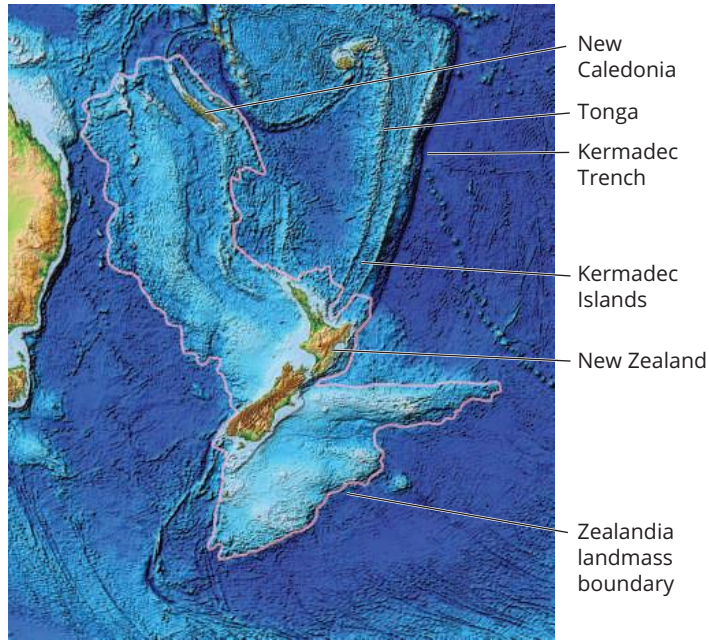


FIGURE 6.2.5 Earth's lithosphere is broken up into major and minor tectonic plates.

Scifile

Australia's new and old neighbours

To Australia's east, the Pacific Plate is sinking beneath the Australian Plate. This subduction forms the Kermadec Trench. Tonga and New Zealand's Kermadec Islands are island arcs forming as a result. New Zealand and New Caledonia were once part of an ancient landmass, more than half the size of Australia, called Zealandia. It is believed that the central part of Zealandia sank under the ocean more than 23 million years ago. The remains of this landmass can be seen on satellite imagery.



Australia's new and old neighbours

SC 2 CHECK YOUR UNDERSTANDING

Name the major tectonic plates on which the world's continents are found.

SC 3 I can explain the forces of motion of tectonic plates

A **force** is a push, pull or twist that can change an object's motion. The tectonic plates are each moving in different directions. Different forces are at play to make this motion occur.

Slab pull and ridge push

New crust is made at places called **mid-ocean ridges**. A **rift valley** at the centre of a mid-ocean ridge is where magma rises to the surface. As the new crust cools and becomes denser, it spreads outwards from the ridge, pushing the tectonic plates apart with a force called **ridge push**. This allows more magma to rise to the surface at the mid-ocean ridge.

At the boundaries, one plate that is denser will **subduct** (sink) into the asthenosphere below due to gravity. This process is called **slab pull** and is thought to be the main driving force for the motion of the tectonic plates.

These two processes occur together so that as sinking crust is destroyed (while subducting) in the mantle, new crust is created at the ridges (Figure 6.2.6).

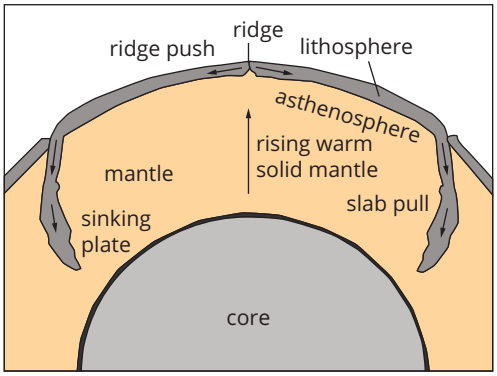


FIGURE 6.2.6 Ridge push and slab pull occur together, creating and destroying sections of tectonic plates in the process.

KEY TERMS

force a push, pull or a twist that can change an object's motion
mid-ocean ridge a mountain system on the floor of the ocean
rift valley a low-lying valley created by the action of a geological rift or split, often at a diverging plate margin
ridge push older crust pushed before new ocean crust at mid-ocean ridges, forcing plates apart
subduction when one plate sinks below another plate during a collision
slab pull a pulling force exerted by older colder and denser oceanic plates sinking into the asthenosphere due to gravity, dragging the rest of the plate with it

SC 3 CHECK YOUR UNDERSTANDING

Choose from the following terms to identify the features and processes labelled A to E in the diagram below.

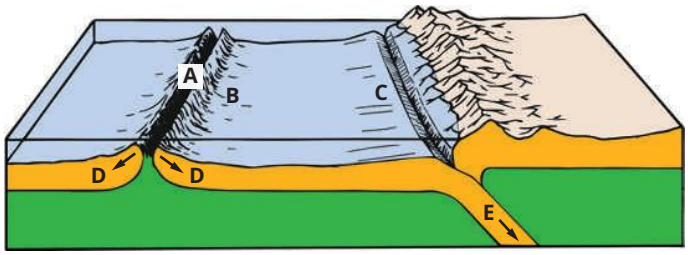
ridge push

mid-ocean ridge

newer oceanic crust

subduction and slab pull

older and denser oceanic crust



Lesson review

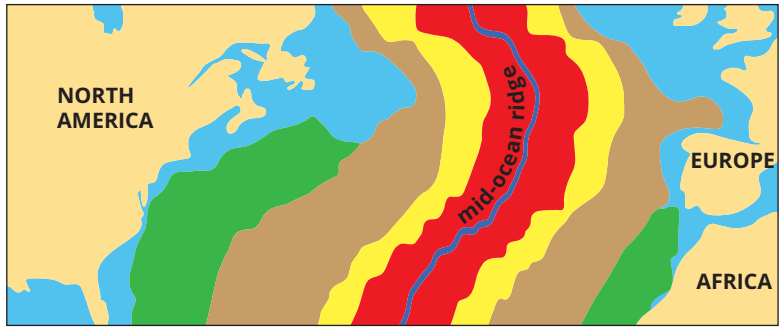
Use these questions to check whether you have met the learning intention for this lesson.

1 You are studying the internal structure of Earth.

- **a** State when scientists think Earth first started to form.
- **b** Describe the influence of gravitational forces on the formation of Earth's layers.
- **c** Compare the properties of the asthenosphere to those of the other sections of the mantle.
- **d** Compare the physical states of the outer core and inner core.

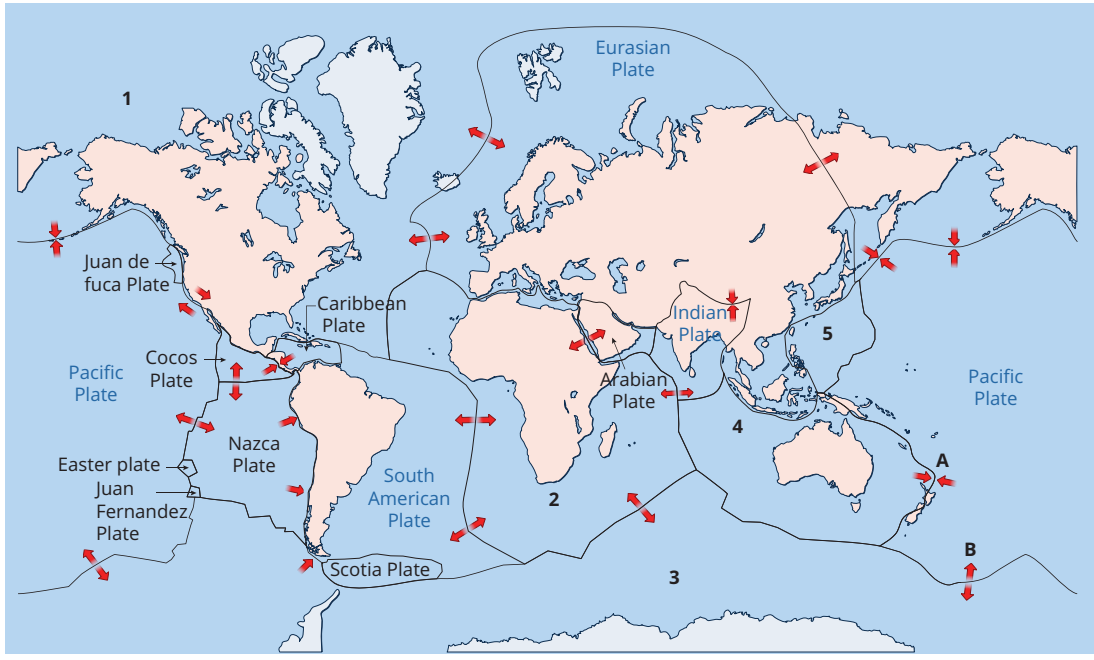
2 Outline how oceanic crust differs from continental crust.

3 The image below shows a mid-ocean ridge in the Atlantic Ocean. Four colours (brown, green, red and yellow) indicate different ages of the oceanic crust. Arrange the four colours in order from youngest crust to oldest.



4 Describe the processes of slab pull and ridge push.

5 Refer to the map of tectonic plates below.



- **a** Name the tectonic plates labelled 1 to 5.
- **b** Slab pull and ridge push occur along many plate margins. Identify which process is occurring at the locations labelled A and B.
- **c** Identify the location (A or B) where the oceanic crust would be younger and less dense. Explain why you selected this location.

6.3 Mantle flow

Introduction

Earth's mantle is a solid layer, so how does it move and flow?

In this inquiry activity, you will investigate the pitch drop experiment and use your findings to communicate how Earth's solid mantle is able to move.

Background

The University of Queensland holds the Guinness World Record for the longest-running laboratory experiment: the pitch drop experiment (Figure 6.3.1). In 1930, Australian scientist and professor Thomas Parnell began the pitch drop experiment. **Pitch** is made from tar, which is used in the surface of roads.

The purpose of the experiment is to demonstrate that a material that seems to be solid can actually flow like a liquid over very long time scales. Pitch slowly forms a drop about every 8 years, but if you were to hit the pitch with a hammer, it would shatter like glass.

The measure of a liquid's ability to flow is called its **viscosity**. Honey has a higher viscosity than water because water flows more easily. Pitch is a highly viscous fluid that appears solid. It has a viscosity around 100 billion times that of water at room temperature.

The pitch drop experiment continues today. The ninth drop fell in April 2014, and the tenth drop is expected to fall in the 2020s.

Aims

To explore the properties of pitch and relate them to the properties of Earth's mantle

To create a video presentation communicating the scientific processes of the movements in the mantle

Plan

Undertake some research in small groups to answer the following questions. Make a note of any secondary sources you use during your research.

1. What is convection, and how does it occur?
2. Describe the properties of the substance pitch, including its viscosity.
3. Explain the purpose of the pitch drop experiment. Include the length of time between drops in your answer.
4. Compare the viscosity of pitch to the viscosity of the mantle.
5. Describe the time scales involved in the motion of the mantle.

Learning intention

To be able to explain how rock in the mantle moves

Success criteria

SC 1: I can compare the motion of pitch to that of the mantle.

SC 2: I can communicate ideas to an audience about the movement of the mantle.

KEY TERMS

pitch a tar-like substance that is semi-liquid when hot and becomes hard when cold

viscosity the measure of a liquid's resistance to flow



FIGURE 6.3.1 The pitch drop experiment started in 1930 at the University of Queensland.

GO TO

Toolkit section 5.3, Using artificial intelligence (AI) in science writing

6 How does convection occur in the mantle if it is a solid?

7 What is a mantle plume?

8 Does convection affect the motion of the tectonic plates?

9 Comment on any scientific debate still occurring on the theory of plate tectonics.

Design

GO TO
Toolkit section 5.1, Methods for presenting scientific ideas

Communicate your findings as a short video explanation. Complete a storyboard to plan your presentation before you create your video.

Your presentation could include an explanation of the pitch drop experiment, a description of the layers of Earth, including the mantle, and how it flows and an explanation of convection and how it occurs in the mantle.

Conduct

Present your video to your teacher and/or classmates.

Improve

Look at how some of your classmates have approached this task, and answer the following questions.

1 What are the strengths of their presentations?

2 How could some of these ideas be used to improve my presentation?

Evaluate

1 Comment on how a greater understanding of Earth's mantle would contribute to the understanding of the movement of tectonic plates.

2 Explain why scientists conduct research into the theory of plate tectonics.

6.4 Geographic evidence for the theory of plate tectonics

Lesson overview

The theory of plate tectonics has been developed over the past 100 years or so and became an accepted theory around the 1960s. Scientists use multiple pieces of evidence to support the theory.

In this lesson, you will learn about geological evidence of plate tectonics, including the formation of mountains and volcanoes, seafloor spreading and magnetic striping.

SC 1	I can identify geographic evidence to support the theory of plate tectonics

Learning intention

To understand geographic evidence that supports the theory of plate tectonics

Success criteria

SC 1: I can identify geographic evidence to support the theory of plate tectonics.

SC 2: I can analyse geographic evidence to support the theory of plate tectonics.

KEY TERMS

geology the study of Earth
geosphere all the rocks, minerals and landforms that make up Earth
convergent boundary a tectonic plate boundary where plates are colliding with each other
fold mountains mountains formed by crust crumpling upwards as plates collide

Identifying geographic evidence

Geology is the science of Earth's structure and the substances it is composed of. The **geosphere** describes any of Earth's layers, from the surface all the way to the core. A constantly growing body of evidence from geologists supports the theory of plate tectonics.

The movement of tectonic plates is not visible to the naked eye, so how can their movement be confirmed?

Some evidence of plate tectonics is easily observed, such as the formation of mountains or the presence of hot spot volcanoes, while other evidence is less obvious. The following examples illustrate different types of evidence supporting plate tectonics.

Mountains

Many of the world's largest mountain ranges are formed where tectonic plates collide at a **convergent boundary**. Examples of mountain ranges formed this way include the Andes, Rocky Mountains and Himalayas. The formation of the Himalayas in Asia over the last 50 million years is a result of the boundaries of the Indian and Eurasian plates crashing into each other (Figure 6.4.1). As the boundaries interact, they push up material from Earth's crust and form **fold mountains**.



FIGURE 6.4.1 Mountains in the Himalayas, including Mount Everest, are still increasing in elevation as the Indian Plate collides with the Eurasian Plate.

Hot spot volcanoes

Volcanoes usually form near plate boundaries, but sometimes they form away from plate boundaries where there are hot spots in Earth's crust. A hot spot is a weak spot in Earth's crust where hot magma collects. Hot spots can occur under continental or oceanic plates and in the ocean they can form chains of islands.

Volcanic islands form where an oceanic plate sits over a hot spot. When the plate moves, the volcanic island moves with it, and a new volcanic island forms above the hot spot.



FIGURE 6.4.2 The Galapagos hot spot has formed the active volcanoes on Fernandina and Isabela Islands.

Volcanic island chains always have at least one active volcano above a hot spot. The older volcanic islands in the chain become firstly inactive (dormant) and then extinct as they move farther from the hot spot. The formation of volcanic island chains is evidence for the theory of plate tectonics.

The volcanoes on Fernandina Island and Isabela Island (Figure 6.4.2), two islands in the Galapagos Island arc, are very active because they are very near or above the Galapagos hot spot.

Seafloor spreading

Seafloor spreading is a process that occurs because tectonic plates are separating. It happens at **divergent boundaries** (Figure 6.4.3). Seafloor spreading is the process by which new crust is formed in rift valleys at the centre of mid-ocean ridges, pushing older crust away from these points.

There is strong geological evidence to support the process of seafloor spreading, including **magnetic striping** and the dating of minerals.

KEY TERMS

divergent boundary a tectonic plate boundary where plates are moving apart from each other in opposite directions

magnetic striping patterns of magnetism trapped in rocks on each side of plate boundaries

Magnetic striping

Earth has a magnetic field. The direction of this magnetic field changes over time. For example, 780 000 years ago, Earth's magnetic field flipped, reversing north and south.

When you hold a compass, the dial aligns itself with Earth's magnetic field so that it points north. Similarly, the particles in certain minerals (such as magnetite) align themselves with Earth's magnetic field.

In the 1950s, scientists analysed rocks along mid-ocean ridges. They found that as they moved further from the ridge on each side, a pattern developed for the direction of Earth's magnetic field (Figure 6.4.4). This phenomenon is known as magnetic striping. The pattern that developed was not in the direction of Earth's current magnetic field itself but rather in how the rocks recorded the direction of Earth's magnetic field at different points and time along the mid-ocean ridge. This pattern, recorded in the rocks, is referred to as 'magnetic striping'.

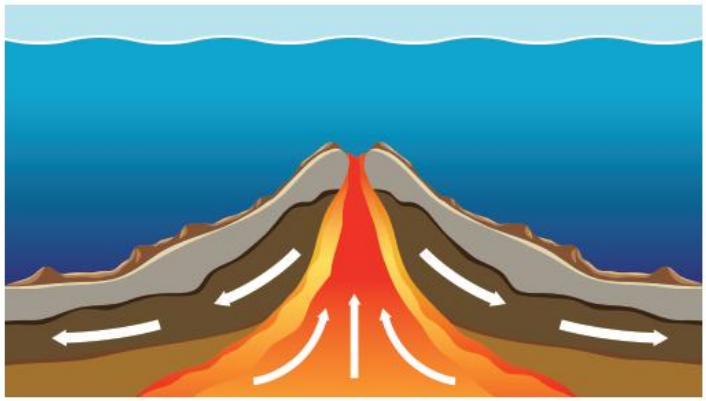


FIGURE 6.4.3 Sea floor spreading occurs at divergent plate boundaries.

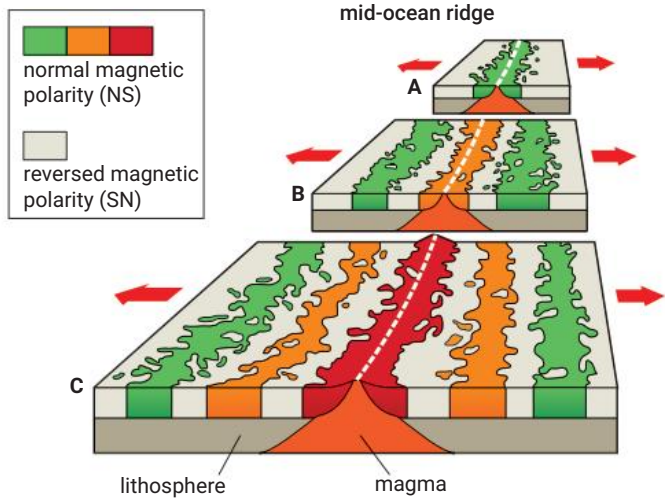


FIGURE 6.4.4 Magnetic striping is due to new seafloor forming on each side of a crack or rift in the crust. The time sequence here goes from A (oldest) to C (youngest).

The symmetrical pattern emerges because, as new crust forms simultaneously along the ridge, the magnetic fields of the rocks at each individual location, or point, align consistently in the same direction. This evidence supports the theory of tectonic plates because it shows that new crust is being produced at mid-ocean ridges. The evidence also supports the theory of ridge push occurring where the plates are pushed apart.

Dating rocks

Scientists can determine the age of rocks by a range of dating techniques, including **radiometric dating**. Radiometric dating measures the radioactive elements in a substance. A radioactive element decays over extremely long periods of time. The amount of radioactivity left can indicate the age of the substance it is found in. This dating technique relies on the fact that radioactive elements decay at predictable rates over extremely long periods of time, and the remaining amount of radioactivity can be used to estimate the age of the material.

KEY TERM

radiometric dating a technique for determining the age of rocks that measures the radioactive elements in a substance

Dating techniques have found that the rocks of the oceanic crust are about 200 million years old. Rocks on continents are older—thousands of millions of years old in some places. These findings show that new rocks are formed closer to divergent boundaries (boundaries where plates are moving away from each other) and that the farther rocks are from these boundary types, the older they are (Figure 6.4.5).

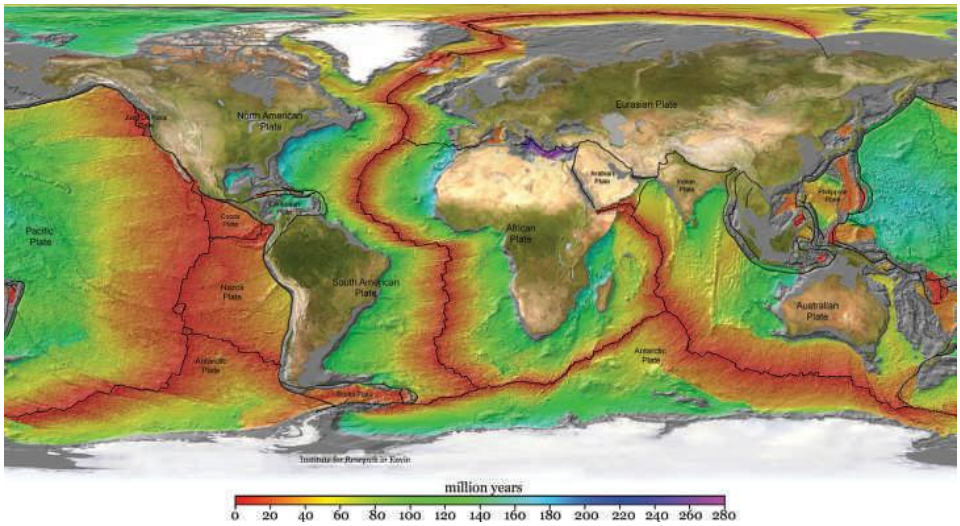


FIGURE 6.4.5 The age of oceanic lithosphere in million years. Newer oceanic crust is found at mid-ocean ridges (shown in red); oceanic crust gradually gets older the farther away it is from the mid-ocean ridges.

This is evidence of plate tectonics because it shows new crust is being produced at mid-ocean ridges (similar to the evidence provided by magnetic striping). The evidence also supports the theory of ridge push occurring at these plate boundaries.

GPS monitoring

The global positioning system (GPS) is a system of satellites, ground-based sites and receivers. GPS is used for navigation. For example, maps on your phone use GPS to show your location.

GPS is used alongside other mapping techniques to accurately determine how fast plates are moving and in which direction. To do this, GPS monitoring stations are embedded (stuck) into the ground so that they move with the continental crust (such as in Figure 6.4.6). The position of these stations is monitored by satellites that record their latitude and longitude over time (Figure 6.4.7). These recordings can show a change in position of a few centimetres per year. GPS monitoring has shown that the Australian Plate is moving north-east at about 7 cm each year. This is physical geographic evidence for the theory of plate tectonics.



FIGURE 6.4.6 The Plate Boundary Observation Station in the Lassen Volcanic National Park, USA, uses GPS data to monitor tectonic movements in the region.



FIGURE 6.4.7 Earth is surrounded by networks of satellites that collect data about the surface of the Earth.

SC 1 CHECK YOUR UNDERSTANDING

Use the descriptors below to identify the type of evidence used to currently support the theory of plate tectonics.

- **a** satellites monitor both the direction and speed of movement of a particular point on Earth's surface
- **b** same patterns of magnetism in the rocks occur at similar distances either side of mid-ocean ridges
- **c** new crust forms at mid-ocean ridges and slowly moves outwards
- **d** continental crust is uplifted as tectonic plates collide with each other
- **e** new islands form as plates move over weak points in Earth's crust
- **f** there is more radioactivity of elements in rocks in oceanic crust closest to the mid-ocean ridges

SC 2 I can analyse geographic evidence to support the theory of plane tectonics

Analysing geographic evidence

Research into the theory of plate tectonics and the inner workings of Earth are ongoing. However, there are still some big unanswered questions. The collection and analysis of evidence can take many forms. The audience of this research also varies, from scientists working in the field of plate tectonics to the general public. Two examples of how evidence for the theory of plate tectonics is communicated for analysis are scientific reports in mainstream news media, and specific scientific findings such as GPS data.

Evidence: Extract from a news article

Understanding Australia's unique earthquake risk

Science Report by Gordon James
Wednesday 22 September 2021

In an unexpected turn of seismic events, a 5.9-magnitude earthquake (with an epicentre in Mansfield, Victoria) rattled various parts of south-eastern Australia today, prompting questions about the country's seismic activity.

It is often thought that earthquakes do not happen in mainland Australia because Australia is at the centre of a tectonic plate. However, although Australia experiences daily tremors, catastrophic quakes above magnitude-5 occur only about twice a year.

Dr Trevor Allen from Geoscience Australia uses a pavlova analogy to illustrate the occurrence of earthquakes in Australia. The analogy works by imagining the Australian Plate as the meringue base of a pavlova with a thin brittle 'crust' lying above a mostly solid meringue 'mantle', with Australia sitting in the centre. If you put your hands on the edge of the meringue and squeeze, cracks will rapidly appear along the edge of the meringue (Figure 1). Continued squeezing will cause strain to also build up in the centre of the crust until cracks begin to appear. Sections of the cracked crust can move, resulting in 'earthquakes'.



FIGURE 1 A pavlova's meringue base can be used as an analogy for the Australian Plate, with Australia sitting in the centre. Pressure applied to the brittle outer crust of the pavlova's base results in cracks, not just near the edge, but also in the centre.

Despite the relative rarity of high-magnitude quakes, Dr Allen dismisses the likelihood of a magnitude 8 or 9 earthquake due to Australia lacking the large, active faults found at plate boundaries. Nonetheless, the country, including major urban centres like Adelaide and Melbourne (Figure 2), faces risks from active fault lines, emphasising the need for earthquake-resistant structures.



FIGURE 2 Damage to an older brick building in Melbourne following today's Mansfield earthquake measuring 5.9 on the moment magnitude scale

To prepare for earthquakes, structural engineer Michael Griffith highlights the importance of the strong building codes introduced in 1995 after the Newcastle earthquake. While modern constructions incorporate earthquake-resistant designs, older unreinforced brick buildings pose a significant risk. Griffith advocates for strengthening existing structures to minimise damage and loss of life, acknowledging the ongoing vulnerability of many historic buildings across Australian cities.

Evidence: GPS data

Ground-based stations are built into rock so they can move when the ground moves. GPS satellites monitor the positions of the ground-based stations over time. There are many of these GPS satellites around the world that monitor different sorts of geological activity, including earthquakes, volcanoes and plate movement.

Data from a Melbourne-based site shows the position of the Australian Plate between 2003 and 2015 (Figure 6.4.8). Numbers rising upwards towards the positive indicate that the plate is moving east. Numbers falling downwards towards the negative indicate that the plate is moving west. Overall, this Melbourne-based site moved in an easterly direction during the data collection period. Scientists can analyse these graphs to find the overall rate at which a plate is moving by determining the gradient. For example, in the graph, you can see that between the years 2010 and 2012, the plate moved approximately 40 mm towards the east.

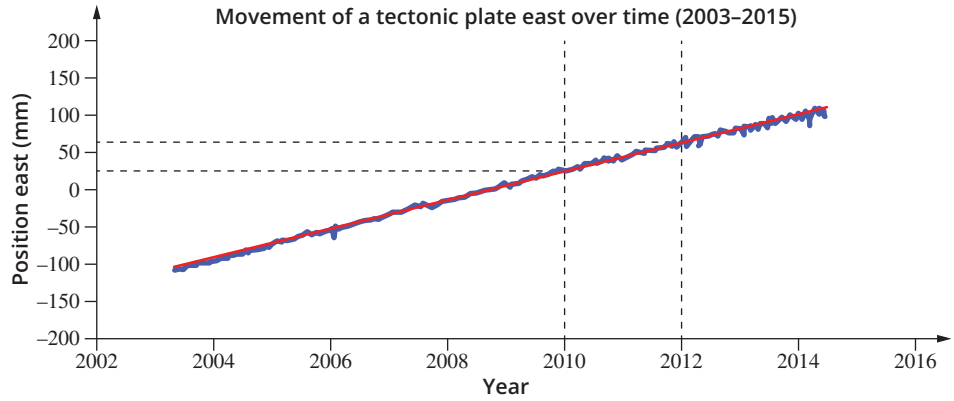


FIGURE 6.4.8 Tectonic plate movement data from a ground-based GPS site near Melbourne, Victoria. Overall, the Australian Plate is moving in an easterly direction.

SC 2 CHECK YOUR UNDERSTANDING

Explain why Australia can experience earthquakes when it is not located near a plate boundary.

Lesson review

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

1. Explain how magnetic striping provides evidence for seafloor spreading.
2. Compare the role of plate tectonics in the formation of Mount Everest and the other mountains in the Himalayas, and the chain of islands in the Galapagos archipelago.
3. Suggest one piece of evidence that may be found at a convergent plate boundary and one piece of evidence at a divergent plate boundary that support the theory of plate tectonics.

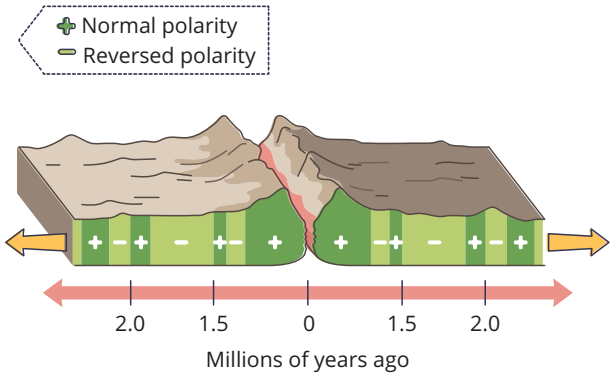
4 The following is representative of data recorded at GPS stations in California in the region of the San Andreas Fault.

Station	Location	Speed (mm/year)	Direction
1	west coast of California	45.8	NW
2	west coast of California	46.2	NW
3	west coast of California	45.2	NW
4	east side of California	3.2	NW
5	east side of California	2.9	NW
6	east side of California	3.3	WNW

a Compare the speed and direction of movement of the land on the west coast of California to the speed and direction of land on the east side of California.

b The San Andreas Fault is part of the boundary between the Pacific and North American Plates. These two plates move in generally the same direction but at different speeds. Where do you predict the fault is located in California?

5 The following diagram shows the magnetic striping along the seafloor either side of a divergent boundary. Refer to the diagram to answer the questions that follow.



a How many episodes of normal polarity are shown on the image?

b Describe what happened to Earth's magnetic field between 2 million and 1.5 million years ago?

c Predict what will happen to Earth's magnetic field in the future.

d Evaluate the usefulness of changes in Earth's magnetic field as evidence to support tectonic plate theory.

6.5 Magnetic striping

Learning intention

To be able to create a model that demonstrates the formation of magnetic striping as evidence for the theory of plate tectonics

Success criteria

SC 1: I can develop a model that demonstrates striping patterns found in rocks on the seafloor.

SC 2: I can use a model to explain to an audience how striping patterns are found in rocks on the seafloor.

Introduction

The iron and nickel in Earth's core give Earth a magnetic field (Figure 6.5.1). The direction of the magnetic field changes over time. When rocks are formed in Earth's crust, the properties of certain minerals in those rocks can be used to determine the direction of the magnetic field at the time of the rocks' formation.

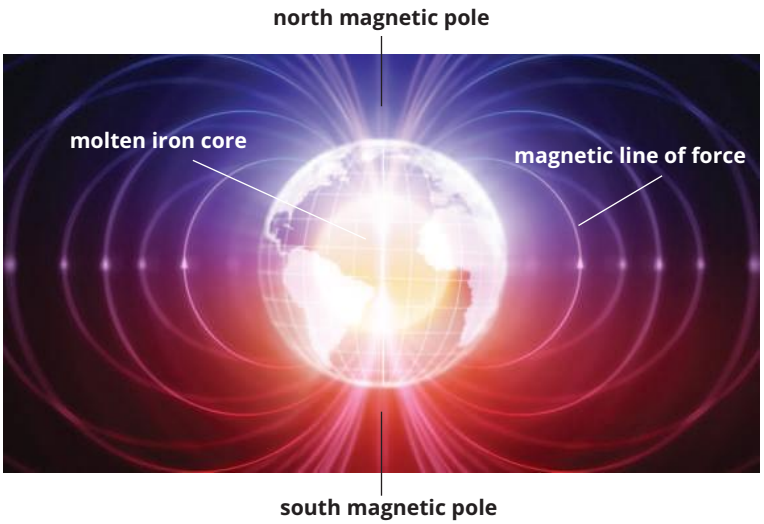


FIGURE 6.5.1 Iron and nickel in Earth's core give Earth its current normal polarity.

These patterns of magnetic striping can therefore provide a timeline back millions of years that can provide evidence for geological change.

In this practical investigation, you will build a model that helps explain magnetic striping and how it provides evidence for the theory of plate tectonics.

Background

The model you will be creating in this activity uses paper to represent tectonic plates moving away from a plate boundary. When this occurs under the ocean between two oceanic plates, it causes seafloor spreading as new rock is created. The lines drawn on the paper represent the changes to the magnetic field.

Aim

To model the magnetic striping patterns in the rocks from seafloor spreading

Materials

- 2 A4 sheets of plain paper
- compass
- bar magnet
- red and yellow pencils or marker pens
- glue
- 2 clothes pegs
- sticky tape
- 2 desks or tables that can be moved

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

- Be careful not to trap fingers in the gap between the desks.

Method

1. Tape the two A4 paper sheets together, short end to short end. Rule a line across each sheet 10 cm from the end that is not taped. Fold the combined paper at the join so the ruled lines are on the inside face of each paper.
2. Push two desks together, leaving a gap of a few millimetres.
3. Push the taped end of the paper down into the gap between the desks until the ruled line is showing in the gap between the tables. This should leave 10 cm of each sheet of paper on the desktop.
4. Place a compass on the desktop. Place a magnet on the desk about 5 cm away from the compass. Ensure the north end of the magnet is pointing away from the compass.
5. Gently fold the ends of the paper down onto the desktop and place a peg on each end to weigh them down, as shown in Figure 6.5.2.

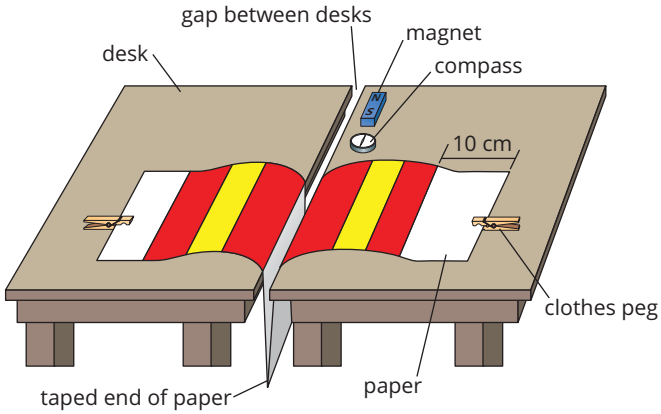


FIGURE 6.5.2 A diagram of the initial set-up for the magnetic striping model

HINT

Make sure that the person pushing the paper up can either see the bench top or can listen to instructions from others in the group as to when to stop pushing upwards.

6 Under the desk, slowly push up on the taped end of the papers until about 2 cm of paper has come out above the desk.

7 Hold the paper still and use the red pencil/pen to colour a 2 cm strip on each sheet of paper, between the opening in the desk and the line on the paper.

8 Spin the magnet around so that the north end is pointing at the compass (this represents the change in the direction of Earth's magnetic field).

9 Repeat steps 6 and 7 but use the yellow pencil/pen to colour in the 2 cm strip. You now should have a red strip and a yellow strip on each side of the gap in the desk.

10 Repeat steps 6–9 until you have three red strips and three yellow strips on each side.

11 On each of the sheets, number the strips 1–6 in the order they were formed. On the oldest strip of rock, write the word 'oldest', and on the youngest strip, write the word 'youngest'.

Conclusion

1 In this model, identify what is represented by the:
   - a gap between the desks
   - b two sheets of paper
   - c magnet
   - d red colour on the paper
   - e yellow colour on the paper.

2 Describe the area of your model that represents the:
   - a youngest rocks
   - b oldest rocks.

Evaluation

Explain how well this model helped you understand magnetic striping along the ocean ridges.

6.6 Modelling the movement of tectonic plates

Introduction

Since 1912, when Alfred Wegener suggested that the continents were drifting across the surface of Earth, geologists and other scientists have discovered so much more about Earth's dynamic processes. The theory of plate tectonics is a continuously evolving area of study with some big questions that remain unanswered.

In this inquiry activity, you will investigate a question related to the theory of plate tectonics and use a mathematical model to determine an answer.

Learning intention

To be able to develop investigable questions that can be answered using a model that represents the theory of plate tectonics

Success criteria

SC 1: I can list ideas and assumptions that a scientific model of plate tectonics might require.

SC 2: I can develop hypotheses that a scientific model of plate tectonics might be able to answer.

Background

In the early 1900s, Alfred Wegener proposed the theory of continental drift, suggesting that continents move across Earth's surface. Today, this idea has been refined into the theory of plate tectonics, which explains that large plates of Earth's lithosphere float on the asthenosphere in the mantle.

But what evidence disproves the theory of continental drift in its original form? And what evidence supports the theory of plate tectonics?

Global positioning systems (GPS) are used to produce data as evidence for the theory of plate tectonics. In this activity, you will analyse some data to answer your research question.

Aims

To develop hypotheses that a scientific model of plate tectonics could answer

To produce a mathematical model that can be used to analyse the motion of plate tectonics

Plan

1. Describe what you know about the theory of plate tectonics.
2. Explain the difference between the theory of continental drift and the theory of plate tectonics.
3. Describe the processes of slab pull and ridge push.

In this investigation, you will be seeking to answer the research question:

Which of the following three processes is the main driving force of plate tectonics: slab pull, ridge push or mantle **convection**?

One theory explaining the motion of plate tectonics is mantle convection. According to this theory, the mantle forms convection cells, and it is the movement of these cells that pushes the tectonic plates.

KEY TERM

convection the transfer of heat through movement in a liquid or gas

Figure 6.6.1 illustrates how these convection currents flow and drive the movement of Earth's crustal plates. When this movement causes plates to converge (collide with each other), one of the plates may be forced under the other plate. This is called subduction.

When this movement causes plates to diverge (move away from each other), magma can move up between the plates.

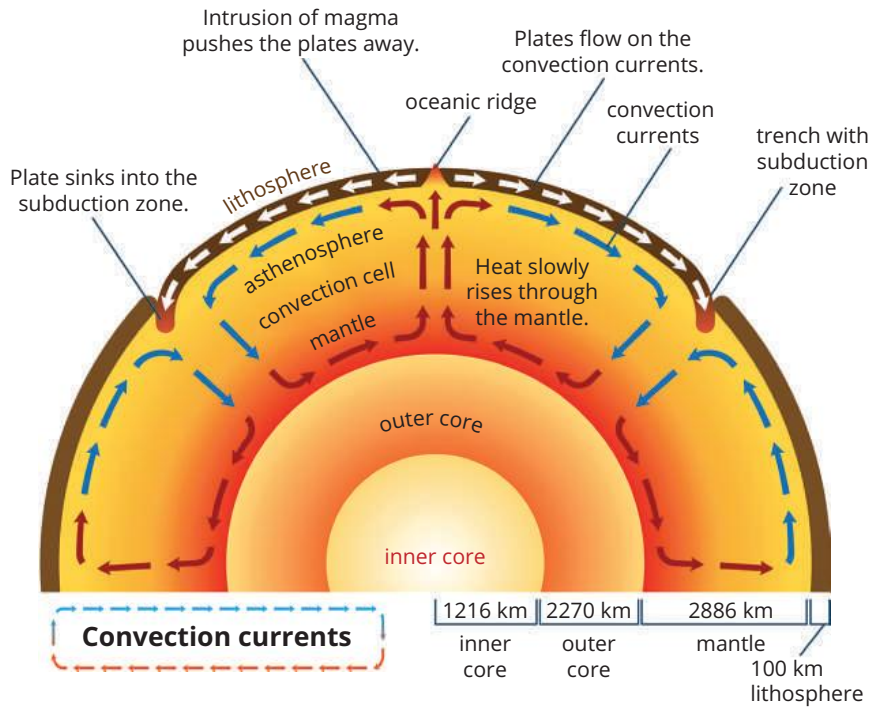


FIGURE 6.6.1 Convection currents moving tectonic plates

4 In groups, discuss how you might determine which of these processes (slab pull, ridge push and mantle convection) is the main driving force in plate tectonics. Make notes on your discussion.

5 Complete the sentences using the words below to develop three hypotheses to test.

convection slower diverging
subducting will faster
will not

a If slab pull is the main driving force, then plates where most of the boundaries are _____ will be moving _____.

b If ridge push is the main driving force, then plates where most of the boundaries are _____ will be moving _____.

c If _____ within the mantle is the main driving force, then the speed of the plates _____ be related to the boundary types.

Design

The following table of data was collected by measuring the distances around each tectonic plate listed, using the ruler function on the software Google Earth Pro.

1 Complete this table.

Tectonic plate	Area (km^2)	Total boundary length (km)	Length of boundary that is subducting (km)	Proportion of boundary that is subducting (%)	Length of boundary that is diverging (km)	Proportion of boundary that is diverging (%)	Average plate speed (cm/year)
Pacific	103 300 000	46 456	16 311		15 110		7.5
North American	75 900 000	33 670	810		11 740		1.5
Eurasian	67 800 000	44 150	1990		10 630		2.9
African	61 300 000	40 560	1960		20 790		2.7
Antarctic	60 900 000	39 600	2170		20 540		1.0
Australian	47 000 000	36 365	7310		14 490		6.5
South American	43 600 000	33 380	1890		8660		1.3
Indian	11 900 000	17 010	1490		3530		5.4
Philippine	5 500 000	11 260	4300		2223		6.8

2 Determine the mathematical relationships you will use to test your three hypotheses to help answer the research question:
'Which of the following three processes is the main driving force of plate tectonics: slab pull, ridge push or mantle convection?'

To do this:

- **a** Decide which type of model you will use (equation, graph, computer model).
- **b** What is the independent variable?
- **c** What is the dependent variable?
- **d** What data will be used to test the slab pull hypothesis?
- **e** What data will be used to test the ridge push hypothesis?
- **f** What data will be used to test the mantle convection hypothesis?

GO TO
Toolkit sections 1.1, Investigable questions: Cause and effect, and correlation and 3.1, Identifying cause-and-effect relationships

Conduct

Use your completed table to plot two graphs. You can also use graphing software.

1 On the first graph, plot a graph of proportion of boundary subducting versus plate speed (slab pull).

2 On the second graph, plot a graph of proportion of boundary diverging versus plate speed (ridge push).

GO TO
Toolkit section 3.2, Creating a line graph using a spreadsheet, 3.3, Outliers and anomalies and 3.4, Analysing a line graph

3 Consider if your two graphs follow a trend. Examples of types of trends are shown in Figure 6.6.2.

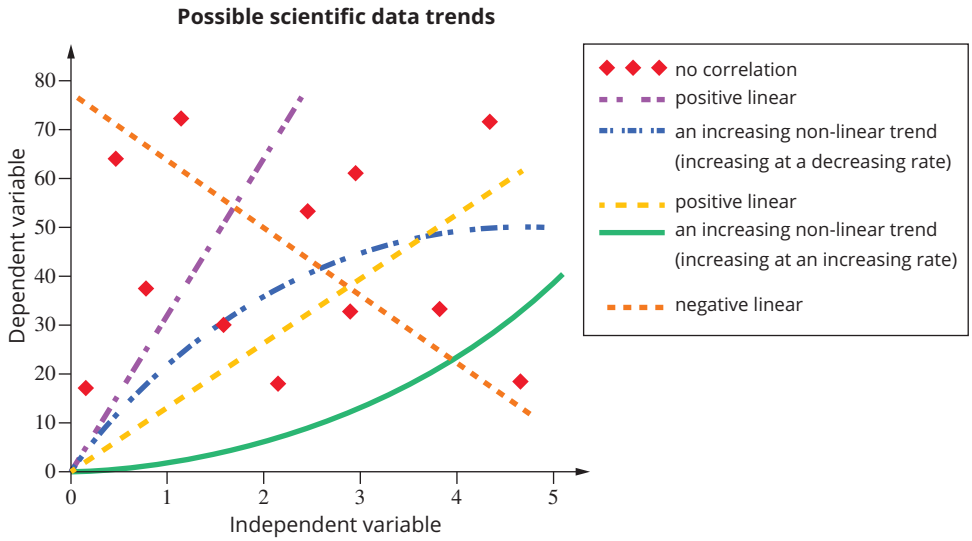


FIGURE 6.6.2 Possible trends in graphs of scientific data

From your analysis of the two graphs, consider the third hypothesis. This hypothesis will be supported if there is no mathematical relationship (or correlation) between the proportion of boundary (%) and average plate speed (cm/year) in both graphs.

Determine whether ridge push, slab pull or mantle convection is the main driving force of plate tectonics.

Improve

1 In your investigation, were there any gaps in the data that could have affected the results?

2 If you were to conduct this investigation again, what could you do differently?

3 If you were to continue this investigation, what other questions would you like to explore?

Evaluate

Develop a conclusion for your investigation. In your conclusion, refer to the aim of the investigation and comment on whether you were successful.

6.7 Biological evidence for the theory of plate tectonics

Lesson overview

When Alfred Wegener first proposed his hypothesis of continental drift, many in the scientific community rejected it. Today, the motion of the continents in relation to the theory of plate tectonics is generally accepted and has a continuously growing body of evidence to support it.

In this lesson, you will learn about biological evidence that supports the theory of plate tectonics (Figure 6.7.1). You will view a timeline of geographical, geological and biological events throughout the history of Earth that shaped it into its current form. You will then construct a timeline of your own.

SC 1	I can analyse biological evidence that supports the theory of plate tectonics

Learning intention

To understand biological evidence that supports the theory of plate tectonics

Success criteria

SC 1: I can analyse biological evidence that supports the theory of plate tectonics.

SC 2: I can construct timelines that represent geographical, geological and biological evidence of events that have shaped Earth into its current form.



FIGURE 6.7.1 The biological remains of Triassic *Cynognathus* have been found in South Africa, Namibia, Argentina and Antarctica.

Biological evidence

The geosphere describes all the layers of Earth. The **biosphere** describes all parts of Earth where life exists. The geosphere and biosphere are constantly interacting with each other. Because of this, scientists can use biological evidence to support a geological theory.

Fossil evidence

To understand the movement of continents (and therefore tectonic plates) over extremely long time scales, scientists look at **fossil** evidence. Fossils of land-based animals and plants that existed millions of years ago have been found across continents that are now separated by oceans (Figure 6.7.2).

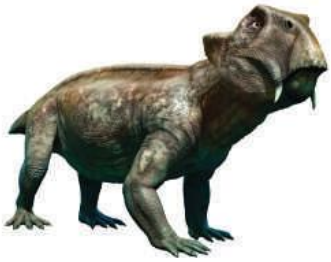
Mesosaurus



Cynognathus



Lystrosaurus



Glossopteris



FIGURE 6.7.2 Four examples of ancient fossils that have been found across continents that are now widely separated

KEY TERMS

biosphere the place where all life exists; consists of Earth's surface and its atmosphere
fossil the preserved remains of a once-living organism

Scifile

Climate clues

In 1912, Robert Scott and his four companions died in Antarctica following their attempt to be the first to the South Pole. With their bodies were 16 kg of rock samples they had collected, which included fossils of *Glossopteris*. This was the first time that evidence of this tropical plant had been found in Antarctica. Also in 1912, Alfred Wegener proposed his Continental Drift theory. The fossils not only indicated that Antarctica was once located closer to the equator, but they were also used by Wegener as further proof of his theory.

KEY TERMS

supercontinent one of several large landmasses that are thought to have divided to form present-day continents

fossil record a list showing the classification of all the species on Earth that have been found as fossils

Scientific evidence suggests that, millions of years ago, all the continents were joined together in a **supercontinent** called Pangaea. Figure 6.7.3 shows where the fossils of *Lystrosaurus*, *Glossopteris*, *Cynognathus* and *Mesosaurus* have been found mapped onto Pangaea.

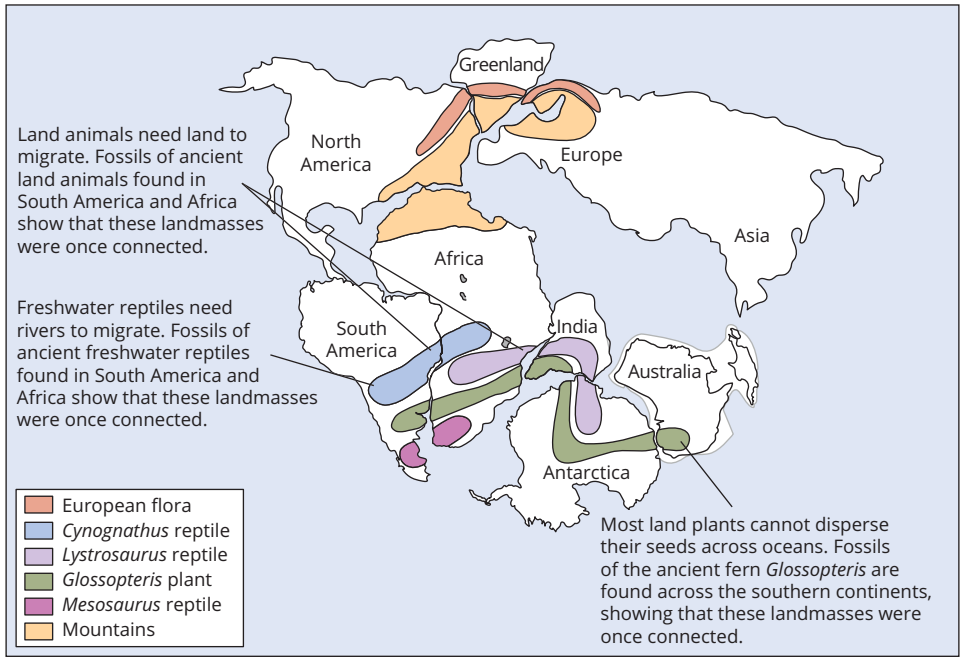


FIGURE 6.7.3 The occurrence of plant and animal species, and mountain ranges, across several continents that were once joined in the supercontinent of Pangaea

For example, fossils of the tree *Glossopteris* have been found in South America, Africa, India, Australia, New Zealand and Antarctica.

The **fossil record** is evidence that supports the theory of plate tectonics.

SCIENCE IN SOCIETY

Gondwana's marsupials

There are over 330 species of marsupials currently in the world. But, despite common thinking, not all of them are in Australia. Australia has about 250 species. One-third of marsupial species, including more than 100 species of opossums, seven shrew possums and the mouse-sized monito del monte (Figure 6.7.4) mainly live in South America.



FIGURE 6.7.4 Monito del monte (monkey of the mountain) is one of South America's marsupial species found in Argentina and Chile.

The fossil record shows marsupial ancestors were numerous in South America 125 million years ago. At this time, Australia, Antarctica and South America were still connected as part of the last remains of the Gondwanan landmass (Figure 6.7.5). Many scientists think marsupials moved outwards from South America, across a much warmer Antarctica and then to Australia. Australia, through seafloor spreading, started to separate from Antarctica about 80 million years ago (mya). By about 55 mya, fossil evidence shows Australia was populated by marsupials, possibly all descendants of a single group that managed to travel across a land bridge and narrow waterway from Antarctica. South America and Antarctica stayed close neighbours until about 35 mya. As Antarctica travelled south to the polar region, the extreme cooling of the climate caused a mass extinction of its marsupials, leaving behind its fossil record.

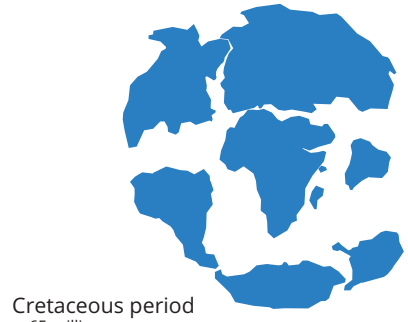


FIGURE 6.7.5 Parts of Gondwana remained connected long enough for the exchange of marsupials between South America and Australia via Antarctica.

Australia's earliest marsupial fossils have been found near Murgon in south-east Queensland.

These fossils from 55 mya most closely resemble a marsupial fossil found in Peru. Marsupials in Australia are thought to have evolved from this form, including two notable extinct marsupials, the marsupial lion and *Diprotodon*, the world's largest marsupial (Figure 6.7.6). South America's marsupials also evolved. They tend not to have pouches but have folds of skin. Notable species include the water opossum or yapok, and the grey four-eyed opossum.



FIGURE 6.7.6 Australia's extinct *Diprotodon* is the world's largest known marsupial, weighing about 2 tonnes.

As scientific knowledge progresses and as analysis techniques improve, some widely accepted hypotheses are challenged. This is the story with the movement of marsupials from one continent to another. The fossil of a mouse-like creature in Australia from about 55 mya bears a close resemblance to South America's monito del monte. This has some palaeontologists speculating that movement of marsupials may also have occurred in the reverse direction, from Australia to South America. Further research is needed to establish the direction or directions of migration.

SC 1 CHECK YOUR UNDERSTANDING

Identify the features of land plants such as *Glossopteris* that prevent the natural spread of the plant from one continent to another. Explain why this is significant in supporting the theory of plate tectonics.

SC 2 I can construct timelines that represent geographical, geological and biological evidence of events that have shaped Earth into its current form

Earth was formed over 4.6 billion years ago. Earth looked quite different 4 billion years ago from today. Each event in the timeline in Figure 6.7.7 explores a key geographical, geological and biological event throughout Earth's history.

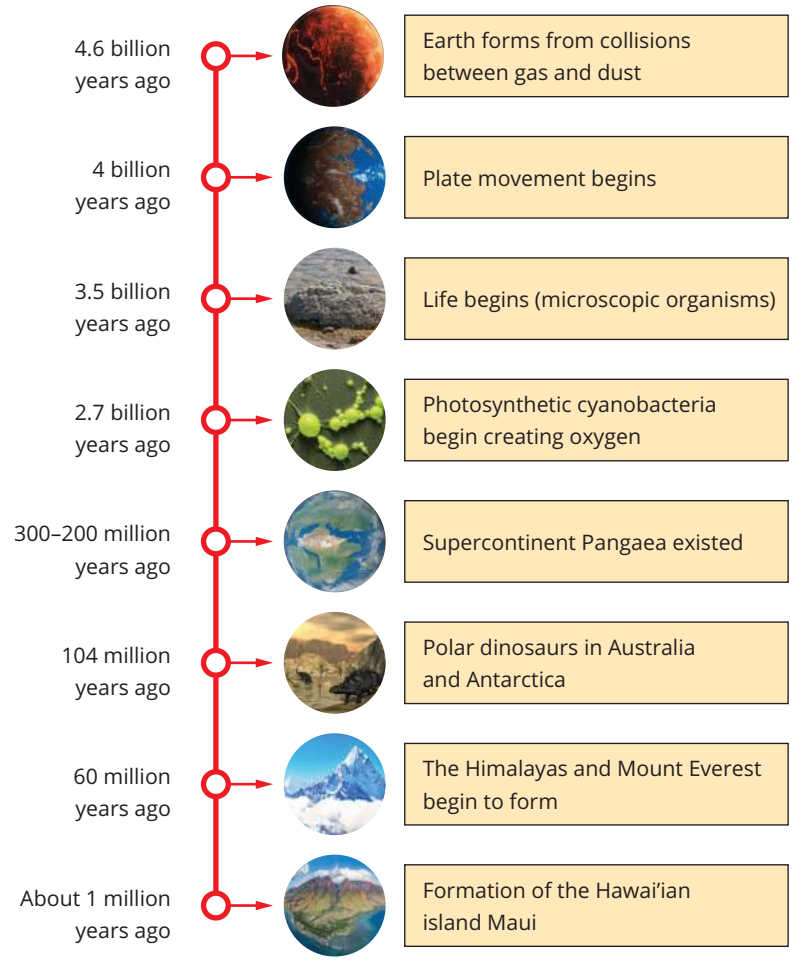


FIGURE 6.7.7 Some key geographical, geological and biological events throughout Earth's history

SC 2 CHECK YOUR UNDERSTANDING

Polar dinosaurs roamed both Australia and Antarctica. Fossils of polar dinosaurs have been found in Dinosaur Cove in Victoria. What can you infer about the relative positions of Australia and Antarctica based on the location of these fossils?

Lesson review

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

1. Scientists think that in Earth's history, continents have joined more than once to form supercontinents. State the name Alfred Wegener gave to the most recent supercontinent.
2. Explain how plants and animals support the theory that all continents were once joined together in a supercontinent.
3. Explain how fossils of *Mesosaurus*, the small freshwater reptile, provide evidence for the theory of plate tectonics.
4. Outline one piece of evidence that supports the theory that Australia and Antarctica were once joined together.
5. Outline the role that cyanobacteria played in Earth's biological history.
6. Create a timeline to show the following strategic points in Earth's changing geography as a result of tectonic plate movement. Ensure the events are in chronological order (arranged in order by time). Note: 'mya' = million years ago.

Relative time	Event
60 mya	North America and Eurasia separated
300 mya	Formation of Pangaea, the most recent supercontinent, and the immense world ocean, Panthalassa
present day	Earth's surface is divided into seven major continental tectonic plates and five major oceans
200 mya	Pangaea divided into Laurasia in the north and Gondwana in the south
250 million years in the future	Predicted formation of a supercontinent made up of Africa, North America, South America and Eurasia
30 mya	Australia and Antarctica separated when Australia moved northwards

6.8 Plate boundaries

Learning intention

To understand the physical phenomena that occur at the different types of plate boundaries

Success criteria

SC 1: I can describe differences between convergent, divergent and transform plate boundaries.

SC 2: I can analyse the role of plate boundaries in the formation of geological features.



FIGURE 6.8.1 The divergent tectonic boundary between the North American and Eurasian Plates forms a surface rift in the Mid-Atlantic Ridge at Silfra in Iceland.

Lesson overview

The movement of the tectonic plates produces different geological features, changing the surface of Earth. The features that are formed depend on the types of plate boundaries that are interacting (Figure 6.8.1).

In this lesson, you will learn about the three types of plate boundaries and the different geological features they can produce.

SC 1 I can describe differences between convergent, divergent and transform plate boundaries

There are three different types of plate boundaries that are defined by the motion of the plates.

Convergent boundary

A convergent boundary is a boundary at which plates are being pushed together (Figure 6.8.2). Depending on the densities of the plates, one may subduct (go under) the other. Collisions between two continental crusts produce taller mountain ranges as the thicker crust is pushed up on both sides.

Divergent boundary

In a divergent boundary, two plates move apart from each other (Figure 6.8.3). New crust forms at a divergent boundary as magma rises from the mantle to Earth's surface between the two plates.

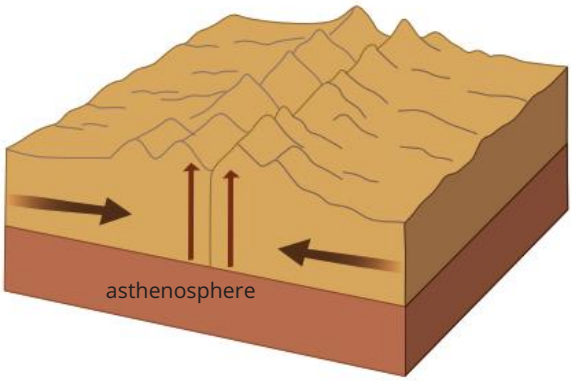


FIGURE 6.8.2 Continental plates at convergent plate boundaries result in the uplift of the lithosphere to create mountain ranges.

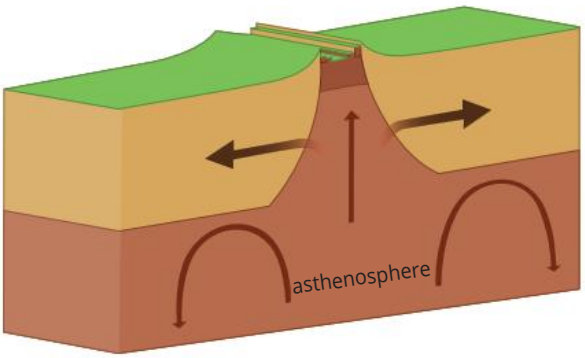


FIGURE 6.8.3 At divergent plate boundaries, tectonic plates move apart, allowing magma to rise to the surface.

Transform boundary

In a **transform boundary**, two plates move alongside each other, either in opposite directions or in the same direction but at different speeds (Figure 6.8.4). This movement sometimes generates earthquakes as pressure created by the movement is released.

KEY TERM

transform boundary a tectonic plate boundary where plates are sliding past each other either in opposite directions or in the same direction but at different speeds

SC 1 CHECK YOUR UNDERSTANDING

Identify the type of plate boundary that shows the following features.

a Plates slide past each other either in opposite directions or in the same direction but at different speeds.

b Plates collide with each other, resulting in subduction or the formation of mountain ranges.

c Plates are moving apart from each other resulting in the formation of new crust at the plate boundary.

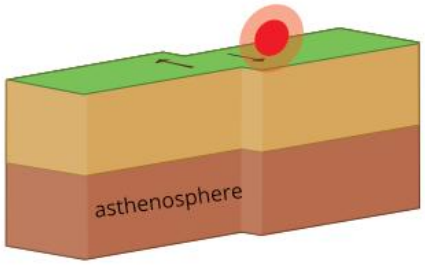


FIGURE 6.8.4 At a transform plate boundary, tectonic plates move alongside each other, sometimes resulting in earthquakes.

SC 2 I can analyse the role of plate boundaries in the formation of geological features

The interactions of different types of plate boundaries form geological features. The outer crust of Earth can be categorised as either continental or oceanic. Oceanic crust is generally denser than continental crust. This difference in density can cause different formations to occur at plate boundaries.

Mountains

When the crust crumples and deforms, it can produce fold mountains.

The crust can be manipulated in two ways (Figure 6.8.5).

- At a convergent boundary of two continental plates, one plate may subduct under the other, but generally the plates are pushed upwards to form mountain ranges such as the Himalayas, due to their similar densities.
- At a convergent boundary between oceanic and continental crust, the denser oceanic plate subducts under the continental crust. During this process, the continental plate deforms and can create mountains and volcanoes such as in the Andes.

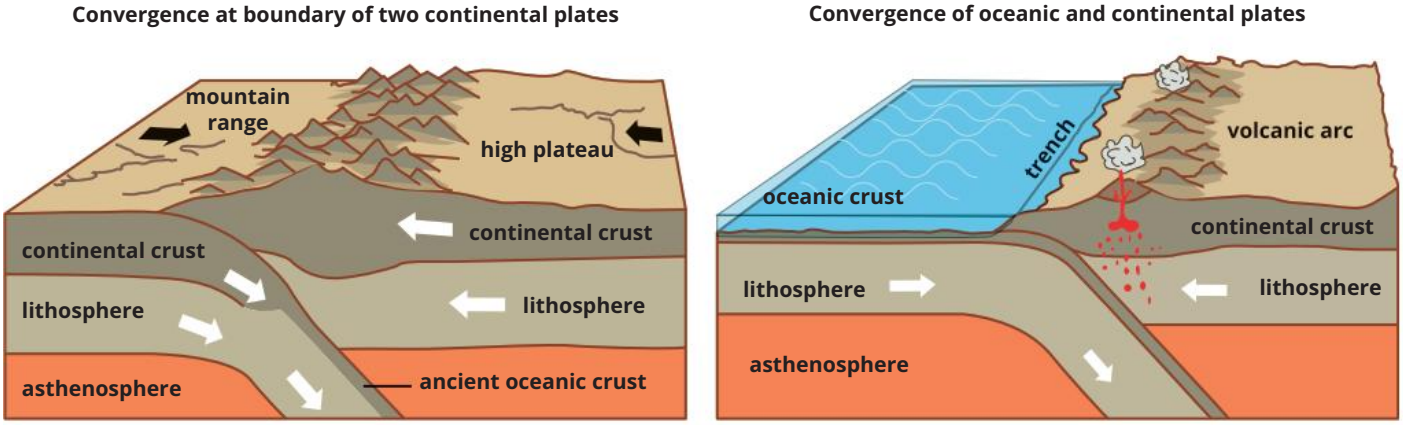


FIGURE 6.8.5 Fold mountains form where two plates converge; when oceanic and continental plates converge, volcanoes also form.

Rift valleys and ridges

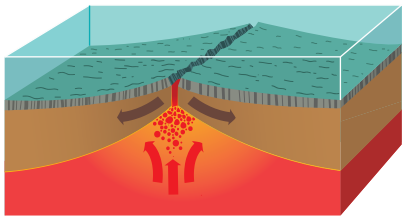


FIGURE 6.8.6 Mid-ocean ridges form either side of a rift valley where magma rises to fill the gap left when two tectonic plates diverge.

Rift valleys are low-lying regions that form at divergent plate boundaries. When two tectonic plates separate or rift, magma rises into the deep crack created. Rift valleys mostly occur at the bottom of the ocean where they are more commonly referred to as mid-ocean ridges (Figure 6.8.6). As the magma solidifies rapidly under water, it creates new oceanic crust to form ridges such as the Mid-Atlantic Ridge.

Rift valleys sometimes occur on continental lithosphere, such as the East African Rift Valley, which is forming where the African Plate and the Arabian Plate are diverging. On land, volcanoes may form when magma reaches the surface.

Volcanoes

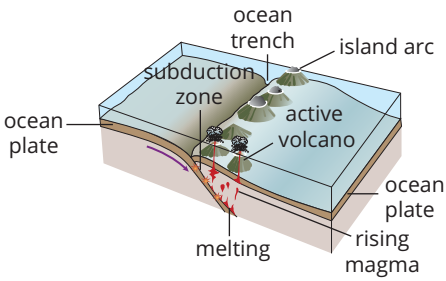


FIGURE 6.8.7 Convergence between two oceanic plates can result in the formation of a volcanic island arc.

Volcanoes can form at various types of plate boundaries, including in rift valleys where divergence occurs. They can also form at:

- convergent boundaries between oceanic and continental crust:
  When an oceanic plate subducts, or moves beneath, a continental plate, it causes the continental plate to deform, leading to the formation of volcanoes in the process (Figure 6.8.5).
- convergent boundaries between two oceanic plates:
  In this scenario, when two oceanic plates converge, they create a chain of volcanic islands, forming a volcanic island arc (Figure 6.8.7).

Volcanoes can also form away from plate boundaries, a category known as hot spot volcanoes.

SCIENCE IN SOCIETY

Krakatoa—a world media sensation

Indonesia has over 150 active volcanoes, the most of any country. These are concentrated in the volcanic island arcs of Java and Sumatra where the Australian Plate subducts under the Eurasian Plate. Between the two lies Sunda Strait. Here, where the crust is believed to be stretched thin, magma rose to the surface to create four volcanoes in the Krakatoa Archipelago (Figure 6.8.8). One of these was known as Krakatoa.

On 26–27 August 1883, Krakatoa erupted violently in a series of explosions, destroying two-thirds of the island and creating a caldera (a depression left by an exploding volcano). Scientists estimate that 25 km^2 of rock was ejected. Ash is estimated to have risen to 80 km in the atmosphere, with the local area in darkness for two and a half days. Global temperatures are recorded as falling by 0.5°C in the year following because the ash blocked radiation from the Sun. Pumice was so thick on the sea that it halted ships.



FIGURE 6.8.8 Krakatoa Archipelago is located in Sunda Strait between the islands of Sumatra and Java in Indonesia.

The eruption was so violent, it was heard in Alice Springs and Perth in Australia, and in Mauritius nearly 5000 km away. Scientists hypothesise that anyone within 16 km would have been deafened.

However, people in this zone were more likely to have been killed by the series of tsunami events triggered by the explosions, the suffocating ash cloud, and pyroclastic flows (eruptions of extremely hot gas, ash and rock, some of which reached the Sumatran coast about 48 km away).

A total of 165 villages and towns were destroyed, and 132 seriously damaged, mostly by the series of tsunamis. Tsunamis were reported in Hawai'i and South America on the other side of the Pacific Ocean. Tsunami surges were reported to be up to approximately 40 m high and took about 36 000 lives in Java and Sumatra. The death toll could be up to 120 000 because many people were reported missing. Human skeletons were discovered washed up on Africa's east coast up to a year after Krakatoa erupted, having been carried by rafts of volcanic pumice across the Indian Ocean. Thousands were injured including those burnt by the pyroclastic flows.

The eruption of Krakatoa was the first natural disaster widely reported in newspapers worldwide.

The recent laying of telegraph cables across oceans allowed the rapid transmission of this news. Krakatoa still makes the news. However, it is now Anak Krakatoa (son of Krakatoa) that is newsworthy. Anak Krakatoa emerged as an active volcano from the sea in the centre of the caldera in 1930 (Figure 6.8.9). In December 2018, part of Anak Krakatoa collapsed into the sea, generating a tsunami that killed more than 400 people and displaced 47 000.



FIGURE 6.8.9 The active volcano Anak Krakatoa (son of Krakatoa) emerged in 1930 in the caldera left behind by the 1833 explosion of Krakatoa.

Ocean trenches

A **trench** is a deep depression in the ocean floor. Trenches usually occur when an oceanic plate subducts (goes under) another oceanic or continental plate (Figure 6.8.10).

KEY TERM
trench a depression in the ocean floor

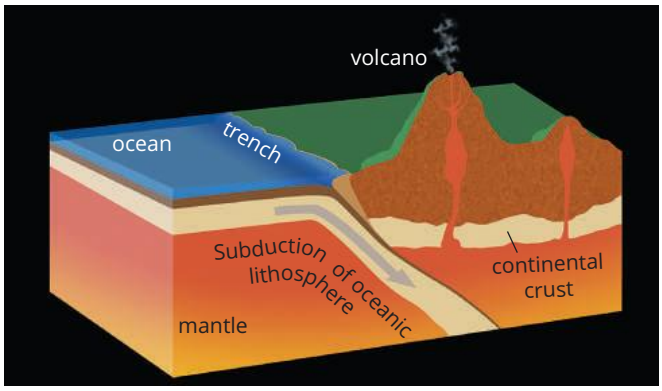


FIGURE 6.8.10 Deep trenches form when an oceanic plate subducts under another tectonic plate.

Scifile

Mariana Trench

In subduction zones, where one oceanic plate is forced beneath another, deep ocean trenches and volcanic activity may result. In the western Pacific where the Pacific Plate subducts beneath the Philippine Plate, the 2550 km long Mariana Trench and the Mariana Islands, a mostly dormant volcanic island arc, have formed. Mariana Trench is Earth's deepest oceanic trench, with the maximum known depth of 11 000 m at Challenger Deep. With Mount Everest standing at 8849 m above sea level, Challenger Deep is the farthest point on Earth's lithosphere from sea level by more than 2 km.

Earthquakes

Almost all earthquakes occur at the boundaries between plates. As the plates interact, sometimes energy is released. When one plate moves suddenly, it is felt as an earthquake.

Most earthquakes occur at convergent boundaries.

Earthquakes are also felt at transform boundaries, such as the San Andreas Fault between the Pacific and North American Plates, which runs through California (Figure 6.8.11).



FIGURE 6.8.11 The San Andreas Fault in California is a transform plate boundary.

SC 2 CHECK YOUR UNDERSTANDING

In the interactions of lithosphere between oceanic and continental plate boundaries, identify the crust that is most likely to subduct, and explain why.

Lesson review

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

1. Define 'convergent plate boundaries', 'divergent plate boundaries' and 'transform plate boundaries'.
2. Explain why collisions between two continental crusts produce taller mountain ranges.
3. Identify the type(s) of plate boundaries involved in the formation of the following geological features.
   - a fold mountains
   - b mid-ocean ridges
   - c earthquakes
4. Explain why hot spot volcanoes are not classed as a geological feature formed at a plate boundary.
5. Compare the formation processes of ocean trenches and mid-ocean ridges.
6. Identify a real-world example of a geological feature at each of the following types of plate boundary. Describe the processes involved in forming them.
   - a convergent
   - b divergent
   - c transform

6.9 Modelling the different types of plate boundaries

Introduction

There are three different types of boundaries between tectonic plates: convergent, divergent and transform. The boundaries produce different geological features due to the interactions between plates.

In this inquiry activity, you will create a model of one of the three boundary types and explore alternative models that you could use to demonstrate the interaction between tectonic plates.

Learning intention

To be able to model the different types of plate boundaries

Success criteria

SC 1: I can design a model that represents the different types of plate boundaries.

SC 2: I can use a model to explain the differences between types of plate boundaries.

SC 3: I can propose alternative models (physical or digital) to demonstrate plate boundaries.

Background

The three boundary types are:

- convergent—where the two plates are moving towards each other
- divergent—where the two plates are moving away from each other
- transform—where the two plates are moving alongside each other (Figure 6.9.1).

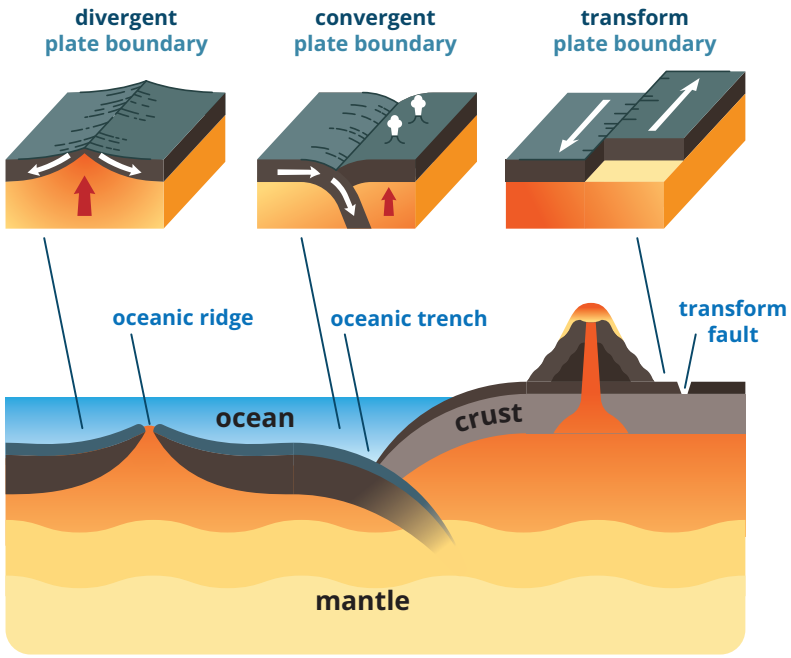


FIGURE 6.9.1 The three types of boundaries between tectonic plates

When plates interact, geological features such as mountains, rift valleys, ridges, trenches and volcanoes are formed.

Oceanic crust is denser than continental crust, and this difference plays a part in the way plates interact between oceans and continents. You can make models by using different household items to show how the plates move and interact (Figure 6.9.2).

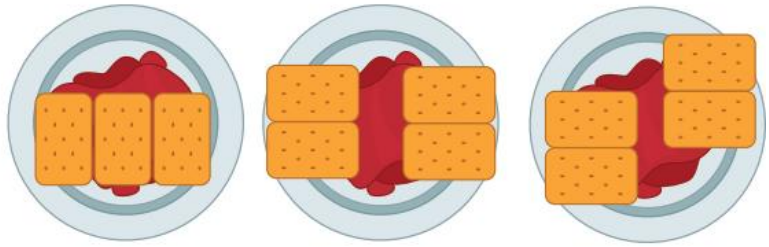


FIGURE 6.9.2 Modelling plate boundaries with biscuits and jam

Aims

To model the interactions between different plate boundaries by using household items

To film a stop-motion video of your chosen plate boundaries

Plan

There are many types of interactions between plate boundaries that you can model. For your investigation, you will model one boundary type, which will be assigned by your teacher.

1. In your group, write down the boundary interaction you will be modelling. Work together as a group and note the types of crust (oceanic or continental) you will be representing with your model. Consider the density of the types of crust (is one crust type denser than the other?). Select a geological formation formed at the boundary such as mountain, rift valley, ridge, ocean trench, volcano or fault.
2. Draw a diagram of your plate interaction. Include labels for the types of crust, lithosphere, asthenosphere and your chosen geological formation, and add arrows to show each plate's direction of movement.
3. Describe the physical properties of both the lithosphere and asthenosphere. Use the following terms in your descriptions: brittle, can flow, liquid, plastic and solid.

Design

1. For your chosen plate boundary, select a household material to use for each layer. Record the materials you have chosen to model the lithosphere and the asthenosphere for both your boundary type and the types of crust involved in the interaction.

Some example materials are:

- biscuits
- jam
- chocolate bars
- play dough
- deck of cards
- honey
- cardboard
- paper.

2 Explain why you chose each material.

3 Present your model design to your classmates. Comment on any design features or materials from your classmates' proposed boundaries that could also work in your boundary type.

4 In your group, finalise your model design by incorporating any improvements identified after the sharing of ideas by the class.

5 Determine how you will set up the recording of movement in your model to create the stop-motion video.

Conduct

1 Collect your materials and set up your model.

2 Manipulate your materials to represent the interaction at your designated plate boundary. As you do so, record the interaction of the 'lithosphere' and 'asthenosphere' to create your stop-motion video.

Improve

1 Review your classmates' videos. Describe how effective their presentations were at demonstrating the different boundary types.

2 What could you do to improve your own model?

Evaluate

1 Explain how each model showed the differences between plate boundaries.

2 In this activity, you made a physical model of a plate boundary and used digital media to communicate it. Write a proposal to a STEM company about a digital model they could use to demonstrate the different plate boundaries and the importance of understanding plate tectonics. Your proposal could include:

- software used or how the model is built
- format of communication
- annotations of the model
- three key impacts of plate tectonics on the environment.

6.10 Investigating the effect of earthquakes

Learning intention

To be able to develop and test a hypothesis to explore scientific models

Success criteria

SC 1: I can write a hypothesis that examines how design affects a model building during an earthquake.

SC 2: I can design an experiment to test a variable that would affect a model of a building in an earthquake.

SC 3: I can evaluate the experiment and recommend improvements to the method.

Introduction

Many towns and cities around the world are built in areas that have a high risk of earthquakes. The city with the largest population in the world, Tokyo, with 37 million people, is also one of the cities most at risk of an earthquake. Hundreds of minor earthquakes are felt by people in Tokyo every year, and the risk of a major earthquake is very high. All new buildings in Tokyo are designed to withstand the forces of an earthquake (Figure 6.10.1).

In this inquiry activity, you will investigate how building design can reduce the risk of damage to buildings in an earthquake.



FIGURE 6.10.1 This apartment building in Tokyo, Japan, is covered with earthquake-resistant reinforcement.

Background

Architects use many techniques to try to make buildings resistant to damage from earthquakes.

These include:

- changing the distribution of weight in a building to improve the balance and prevent the building from toppling over
- increasing the width of the building's base to make it more stable
- using base isolation, in which lead–rubber bearings or pads are placed between the building's foundations and the building structure above; during an earthquake, these bearings reduce the impact of the ground's movement on the building
- constructing a strong frame around the building that can absorb the impact of the earthquake.

Aim

To test how variables may affect the performance of a building in an earthquake area

Hypothesis

Decide on a question you want to investigate. Your question could be about how effective changing one of the variables is at reducing damage to a tall building, or it could be about comparing the effectiveness of two, three or four of the variables. The four variables that can be tested are:

- changing the distribution of weight
- increasing the width of the building's base
- isolating the building's base
- using an external frame.

State what you are going to investigate and write a hypothesis for your investigation.

HINT

What you decide to investigate will depend on the time you have for the experiment, the resources available and guidance from your teacher.

Plan

Use the following information to guide the design of your experiment. Write notes that will help you design your investigation.

At each planning step, record notes as a group.

1 In your group, decide how you will make your 'earthquake generator', which is what will rock your model buildings back and forth. Figure 6.10.2 shows a hardcover book resting on pencils. This is the simplest method, but you will need to consider this as an experimental variable and control its effect. Record your key ideas.

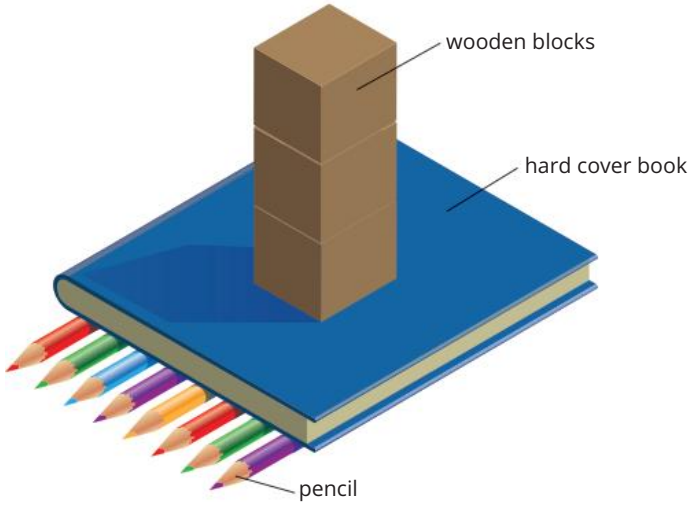


FIGURE 6.10.2 A simple 'earthquake generator'.

2 Your buildings must include three or four sections. Make different sections (floors) about 10 cm high, with a base of about 5 cm by 5 cm for each section. You can change these measurements if enough material is available. Sketch or note how you will make your building.

3 To test variable 1 (changing the distribution of weight), you will need to make the sections from different materials such as wood or polystyrene.

To test variable 2 (increasing the width of the building's base), you will need to make some sections different widths.

To test variable 3 (isolating the building's base), you can use an ice-cream container and different materials such as ball bearings, sand, marbles or 'hundreds and thousands'. If you want to try something else, ask your teacher.

To test variable 4 (using an external frame), you could construct a frame with lengths of wood, wooden skewers or straws.

Note which variable you will investigate and how you will change it in the investigation.

4 Build your first model building. Place it on your earthquake generator and test its performance.

Decide how you will record this process, which might involve filming the experiment.

Remember that how you operate your earthquake generator is a variable. Record your key observations and measurements.

Materials

The materials available for your investigation include:

- plastic modelling clay
- hardcover book
- pencils
- wooden blocks, polystyrene blocks, cardboard boxes
- ice-cream container
- ball bearings, marbles, sand, 'hundreds and thousands'
- other materials that you select
- stopwatch
- ruler.

Design

Write a step-by-step method for your investigation. Include how you will control variables other than the one you are testing, and how you will record your results.

Conduct

Conduct your experiment. Record your results and write a conclusion that relates to your hypothesis.

Improve

Suggest two things you did, or two things you could add to your experiment design, to improve the quality of the data.

Evaluate

Evaluate how well your results supported your hypothesis. Use direct evidence from your data in your answer.

6.11 Cultural building techniques

Introduction

Earthquakes have been one of the most destructive natural disasters throughout history, causing widespread damage to buildings, infrastructure and communities. However, over time, cultures around the world have developed unique techniques to construct and repair buildings that can withstand the seismic activity caused by earthquakes (Figure 6.11.1). In this inquiry activity, you will explore how cultural building techniques led to the development of structures and materials that are better able to withstand the effects of earthquakes.



FIGURE 6.11.1 Bamboo scaffolding surrounds a temple at Bagan, Myanmar, undergoing restoration after a 6.8 magnitude earthquake.

Learning intention

To be able to explore how cultural building techniques led to the development of structures and materials better able to withstand the effects of earthquakes

Success criteria

SC 1: I can describe how culture influenced the development of scientific knowledge.

SC 2: I can explain how bamboo is used in structures in earthquake-prone areas.

SC 3: I can design a building that withstands the effects of earthquakes.

Background

Earthquakes occur when two tectonic plates in Earth's crust suddenly slip past each other, releasing energy in the form of seismic waves. These waves can cause the ground to shake violently, which can lead to significant damage to buildings and infrastructure. Throughout history, earthquakes have been a major challenge for builders and architects around the world. However, different cultures have developed unique techniques for building structures that are able to withstand seismic activity. For example, in earthquake-prone areas of Asia, bamboo has been used as a building material for centuries due to its flexibility, strength and availability (Figure 6.11.2).



FIGURE 6.11.2 Workers in Bali use bamboo and wood in the construction of a building.

Aim

To understand how culture influences earthquake-resistant building techniques and materials, and to apply this knowledge to design safer structures

Plan

1. Research and collect information on cultural building techniques from an earthquake-prone region or regions in the world. Pay attention to the materials, designs and construction methods used.
2. Choose specific cultural construction or building techniques to incorporate into your building design. Explain the cultural influences on your design.

Design

1. Develop a design for an earthquake-resistant building that incorporates the cultural techniques you have chosen. Consider the type of building (residential, commercial, community), the materials used and the structural design.
2. Create a visual representation of your building design. You can use drawing tools or a 3D modelling program.

Conduct

GO TO
Toolkit sections 5.1, Methods for presenting scientific ideas and 5.2, Using scientific language

1. Prepare a presentation that includes the following information.
   - Cultural influences: How does the culture influence the building's design, aesthetics and functionality?
   - Earthquake resistance: What techniques and materials make the building earthquake-resistant, and how effective are they?
   - Comparison with traditional design: How does the chosen building differ from traditional designs in the same cultural tradition, and why?
2. Present your design to the class, using your visual representation and presentation to explain your design choices.

Improve

Complete peer reviews following these steps:

- As a class, decide on your review criteria and how the feedback will be shared.
- Provide constructive and respectful feedback for others. Aim to highlight strengths and potential areas for improvement.
- Reflect on the feedback. If you have time, make some improvements to your presentation.

Evaluate

1. What aspect of cultural building techniques did you investigate in this inquiry activity?
2. In this activity, you explored how cultural building techniques led to the development of structures and materials better able to withstand the effects of earthquakes. What skills did you use during this activity?

6.12 Communication of seismic data

Lesson overview

A tsunami is a large ocean wave or series of waves caused by either a large earthquake on the seafloor, a landslide or a volcanic eruption. Tsunamis are very destructive and can cause loss of human life, so it is important to warn people about any potential threat. Scientists collect seismic data across the Asia–Pacific region, and governments in the region work together to quickly and efficiently share this data so accurate and fast tsunami alerts can be issued. Vulnerable coastal communities can then take appropriate measures to protect themselves (Figure 6.12.1).

In this lesson, you will learn about how seismic data is collected and shared between governments across the Asia–Pacific region to produce tsunami alerts.

SC 1 I can describe how seismic data is collected

Seismic data, which is used to study and monitor earthquakes, is collected through specialised instruments called seismographs. When an earthquake occurs, it releases seismic waves that travel through Earth's crust and other layers. Seismographs are placed on, or in, the ground to detect these waves (Figure 6.12.2). Ground movement caused by the seismic waves is recorded by the seismograph, and is converted into electrical signals that can be analysed.

There are different types of seismographs. Most consist of an internal seismometer, a mass mounted on a spring or a pendulum. The seismometer detects movement when the ground shakes. As the components around the mass moves, electrical signals are generated that are recorded by the seismograph. These signals are then transmitted to a data centre or a recording station where they are processed and analysed by scientists.



FIGURE 6.12.1 A tsunami warning sign on a beach in Thailand gives tourists awareness that they are in a tsunami hazard zone.



FIGURE 6.12.2 Seismographs are regularly checked by technicians.

Learning intention

To understand how seismic data is collected and shared between governments across the Asia-Pacific region to produce tsunami alerts

Success criteria

SC 1: I can describe how seismic data is collected.

SC 2: I can explain how governments across the Asia–Pacific region collaborate and communicate to reduce risks caused by earthquakes.

SC 3: I can describe how seismic data is used by communities to generate tsunami alerts.

KEY TERMS

tsunami a large and destructive ocean wave or series of waves caused by either a large earthquake on the seafloor, a landslide or a volcanic eruption

tsunami alert a public alert issued by governments to warn vulnerable coastal communities about the potential threat of tsunami

Seismographs are not just located on land. There are also seismographs on the ocean floor to monitor underwater earthquakes and potential **tsunami** events (Figure 6.12.3). These ocean-bottom seismographs are deployed in arrays (organised networks). They are connected to buoys on the surface that transmit the data to a tsunami warning centre for analysis. The buoys themselves register abnormal changes in sea level.

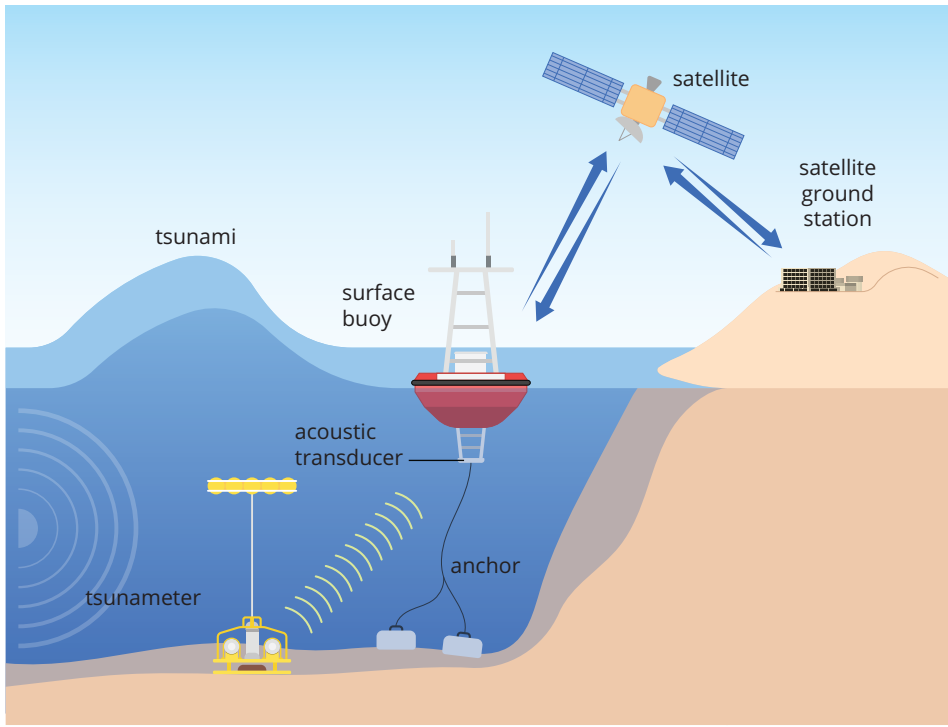


FIGURE 6.12.3 Ocean-bottom seismographs in the tsunami warning system transmit seismic data via a buoy and satellite.

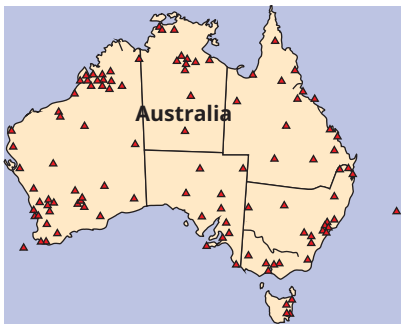


FIGURE 6.12.4 Australia's seismic network has more than 150 locations.

Seismographs are often placed in networks to monitor earthquake activity in a region (Figure 6.12.4). This allows scientists to collect data from multiple seismographs and triangulate or map the epicentre location, depth and magnitude of an earthquake. By analysing the seismic data, scientists can gain insights into the behaviour of earthquakes, such as their frequency, intensity and patterns over time.

Seismic data collected from seismographs is crucial for understanding and predicting earthquakes, and it is used by scientists, engineers and governments to assess earthquake risks and to develop early-warning systems and **tsunami alerts** in regions prone to earthquakes and tsunamis.

SC 1 CHECK YOUR UNDERSTANDING

Outline how data collected from a network of seismographs can be utilised by scientists and governments.

SC 2 I can explain how governments across the Asia–Pacific region collaborate and communicate to reduce risks caused by earthquakes

Natural hazards such as earthquakes and tsunamis cannot be prevented. However, their impacts can be reduced through measures that try to prevent large-scale disasters.

Governments across the Asia–Pacific region collaborate and communicate with each other in various ways to reduce earthquake impacts (Figure 6.12.5). One of the key methods is through regional and international organisations such as the Asia–Pacific Economic Cooperation (APEC), the ASEAN Committee on Disaster Management (ACDM) and the Pacific Tsunami Warning Center (PTWC). These organisations facilitate communication and coordination among member countries for disaster risk reduction, including earthquake and tsunami preparedness and large-scale disaster prevention.

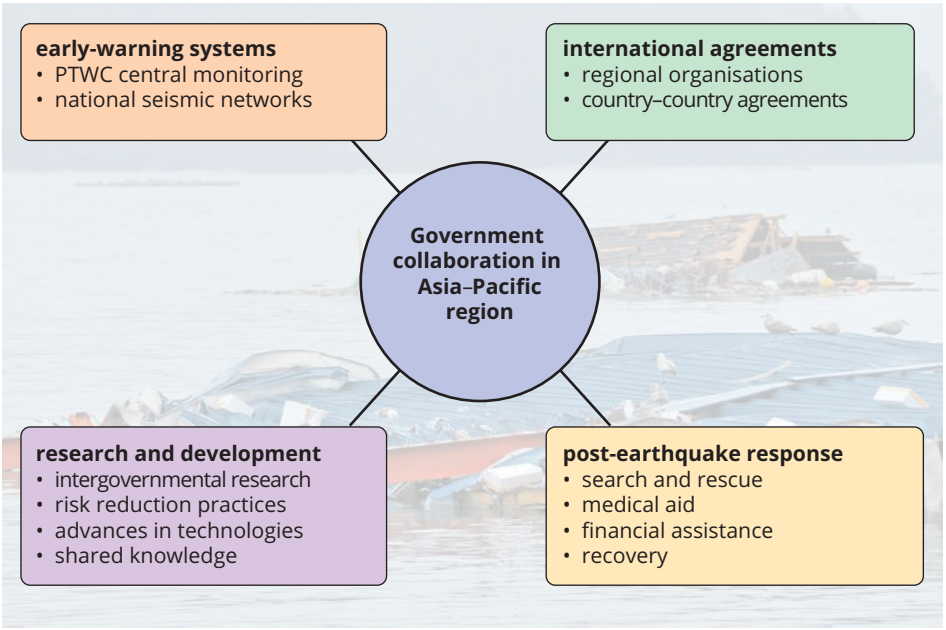


FIGURE 6.12.5 Examples of some government collaboration measures in the Asia–Pacific region

Early warning systems

The Pacific Tsunami Warning Center (PTWC), based in Hawai'i, provides real-time seismic data and tsunami alerts to countries across the Pacific Ocean and countries in the Asia–Pacific region. This allows governments to communicate quickly with each other and issue timely alerts to potentially affected areas. Australia contributes to this coordinated effort by providing sea level and seismic information to PTWC.

Agreements between countries

Countries in the Asia–Pacific region work together to share knowledge and resources for earthquake prevention and response. This can be through regional and international organisations, where knowledge about the best ways to reduce risk is shared through education and training.

Individual countries also work closely together. For instance, Japan, a country with advanced earthquake preparedness measures, has provided technical assistance and training to other countries in the region, such as Indonesia and the Philippines.

Research and development

Governments work together to undertake research, develop ways to monitor earthquake activity, and to assess and reduce risk. For example, countries may work together to develop new technologies, such as better seismographs, tsunami arrays or earthquake prediction models. By sharing knowledge and resources, they can collectively improve earthquake expertise and technologies.

Post-earthquake response



FIGURE 6.12.6 A ship stranded on land after the 2011 Great Tohoku tsunami in Japan

After an earthquake occurs, governments in the region collaborate and support each other in search and rescue, medical and financial aid, and recovery. For example, after the devastating Great Tohoku earthquake and tsunami in Japan in 2011 (Figure 6.12.6), many countries in the region, including Australia, sent rescue teams, supplies and financial assistance to support Japan's recovery efforts.

Collaborative efforts and rapid communication among countries in the region are crucial for effective earthquake preparedness, response and recovery. The reason for this is that the locations and impacts of earthquakes and tsunamis are not restricted by the borders of countries. An earthquake in one location can affect several countries some hundreds of kilometres away.

SC 2 CHECK YOUR UNDERSTANDING

Outline three ways in which governments across the Asia–Pacific region collaborate and communicate with each other to reduce the impacts of earthquakes.

SC 3 I can describe how seismic data is used by communities to generate tsunami alerts

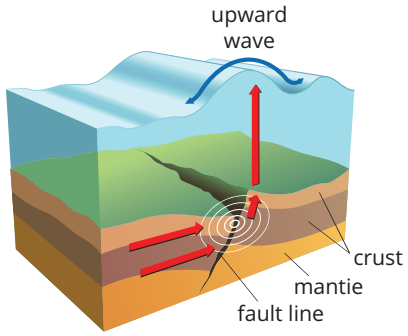


FIGURE 6.12.7 Vertical displacement of water occurs above the epicentre of an undersea earthquake.

Seismic data is used by communities to generate tsunami alerts. This is done by monitoring and analysing the vibrations, or seismic waves, caused by earthquakes and volcanoes.

Tsunamis

When an underwater earthquake occurs, it can displace the water column, which is the entire vertical section of water above the seafloor, extending from the ocean's seafloor up to the surface. This displacement of the water column can trigger the formation of a tsunami (Figure 6.12.7). In the open ocean, tsunamis can travel at a speeds greater than 800 km/h.

Seismograph locations

Seismographs are strategically placed near tectonic plate boundaries around the world, including in the ocean floor and along coastal areas, to detect seismic waves generated underwater (Figure 6.12.8). When a significant earthquake is detected, the seismic data is quickly analysed by experts who can determine the magnitude, location and depth of the earthquake.

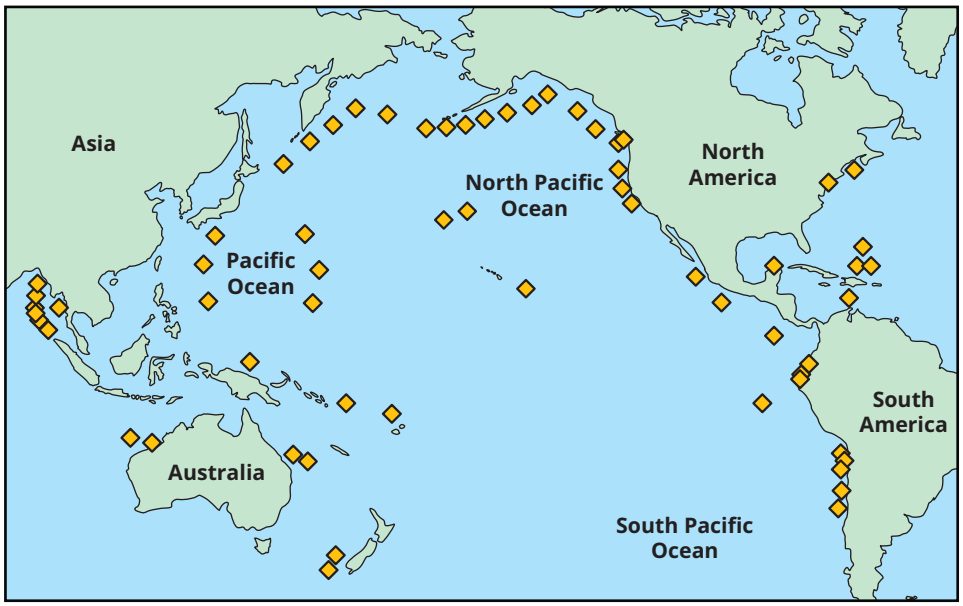


FIGURE 6.12.8 A map showing the array of the DART tsunami monitoring systems, mostly near tectonic plate boundaries, in the Pacific and Indian Oceans

Tsunami alerts

If applicable, an earthquake's epicentre location, magnitude and depth are then used to generate timely and accurate tsunami alerts issued to communities in at-risk coastal areas. These alerts inform them of the potential threat, helping communities in coastal areas to take appropriate measures to protect themselves from the potential danger of tsunamis.

Tsunami alerts in Australia

In Australia, the assessment of a tsunami risk is conducted by the Joint Australian Tsunami Warning Centre (JATWC), which is operated by Geoscience Australia and the Australian Bureau of Meteorology (BOM). Geoscience Australia operates Australia's network of seismic stations and has access to more data from international networks. Seismic data can be quickly analysed by experts at Geoscience Australia to determine if an earthquake has the potential to generate a tsunami. If so, Geoscience Australia alerts BOM of the possibility of a tsunami being generated. BOM then uses additional data, including sea level monitoring from a network of tide gauges and ocean buoys, to confirm the tsunami threat, and to forecast tsunami arrival times and impact on coastal areas. Tsunami warnings are issued by BOM (Figure 6.12.9).

Scifile

Indian Ocean Tsunami Warning and Mitigation System (IOTWS)

Countries in the Pacific region have long had early-warning systems that use seismic data to predict tsunamis. Those systems provide valuable time for coastal communities to evacuate and prepare. In 2004, no such system was in place in the Indian Ocean. On 26 December 2004, the Indian Ocean Tsunami impacted nearly the entirety of the Indian Ocean, causing over 230 000 deaths. Since then, Australia and other countries have assisted in developing measures to improve Indian Ocean Tsunami readiness. This includes installation of tsunami-detection buoys, early-warning communication systems and education of at-risk populations.

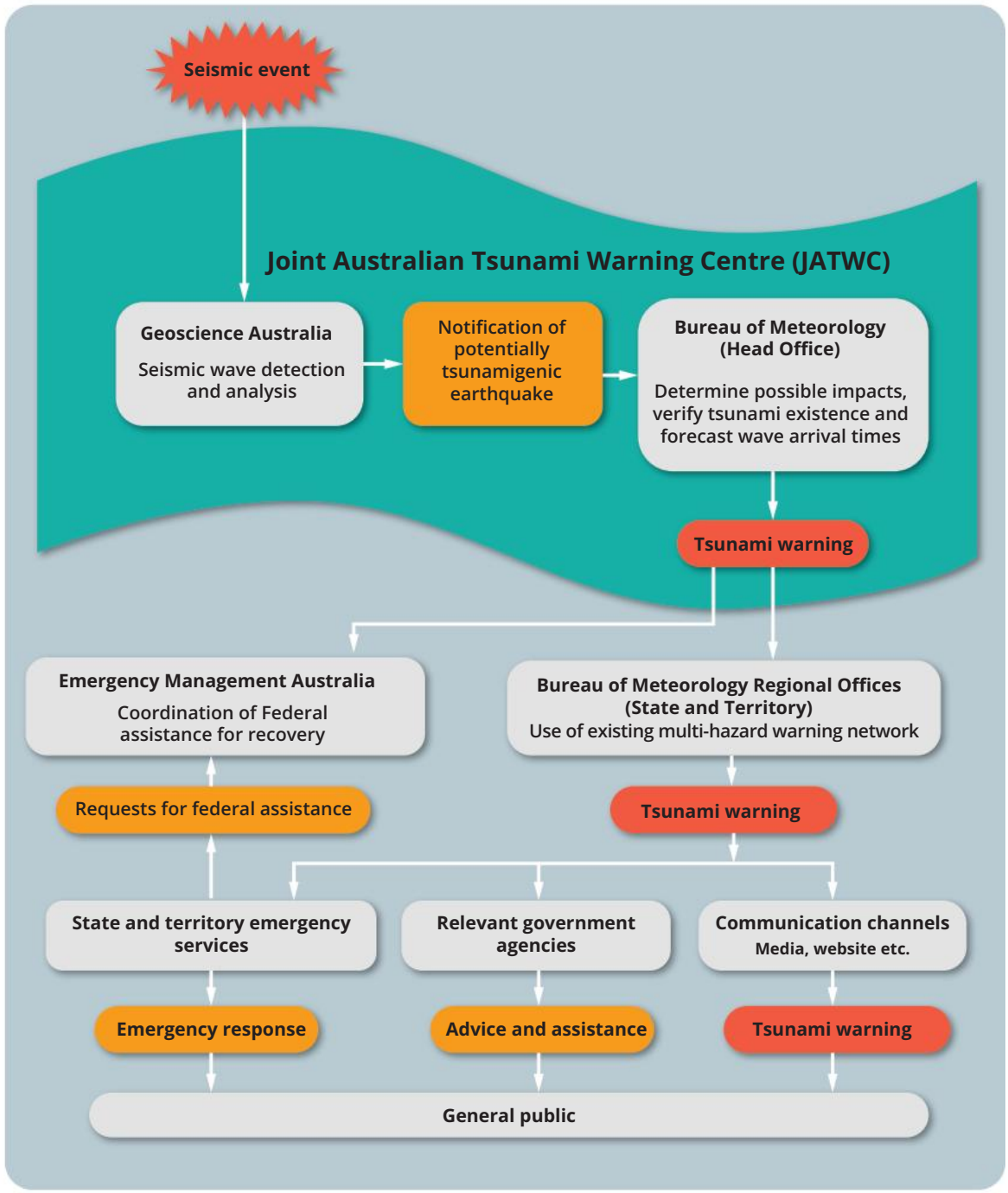


FIGURE 6.12.9 Australian tsunami warning system

Communication of alerts

Based on the analysis of all data sources, tsunami alerts can be generated and communicated to relevant authorities, emergency services and communities at risk through various communication channels. These include media broadcasts, emergency warning systems and online platforms. Alerts provide crucial information to communities, enabling them to take appropriate actions, such as evacuating coastal areas or seeking higher ground, to reduce the potential impact of a tsunami.

It is important to note that generating tsunami alerts is a complex process that involves the rapid coordination of multiple agencies and organisations. Seismic data is just one of the many pieces of information used in this process to protect vulnerable coastal communities in Australia and around the world.

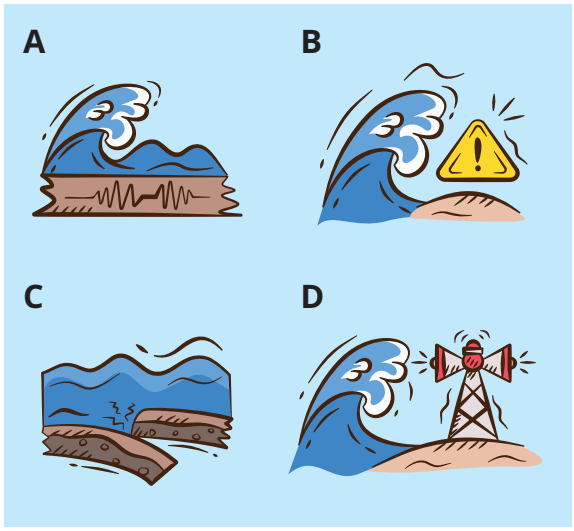
SC 3 CHECK YOUR UNDERSTANDING

Compare the roles of Geoscience Australia and the Bureau of Meteorology in determining if an earthquake triggers a tsunami warning.

Lesson review

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

1. Explain the difference between a seismometer and a seismograph.
2. Explain why the network of seismographs on the ocean floor, and their associated buoys, are located where they are in the Pacific Ocean.
3. Outline three ways in which Australia and other nations have collaborated with countries in the Indian Ocean region to better predict tsunamis.
4. Identify three pieces of information that seismologists can determine from a network of seismographs when an earthquake occurs.
5. Explain how an undersea earthquake can create a tsunami.
6. An undersea earthquake has occurred, resulting in a tsunami.



   a. Arrange the letters A–D into the correct sequence of events that authorities will follow to keep communities safe. Explain what is happening at each stage.
   b. Identify the government agencies responsible for the detection of earthquakes, determination of a tsunami threat and broadcasting of warnings in Australia.

6 Theory of plate tectonics

Topic summary

The key concepts included in this topic are:

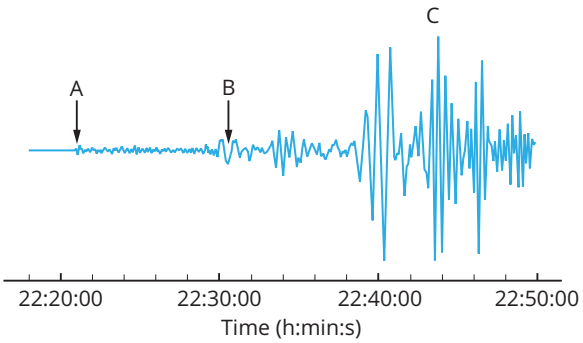
- The theory of plate tectonics explains the patterns of earthquake and volcanic activity around the globe.
- Rock in the mantle moves through convection, most likely driven by slab pull and ridge push in the lithosphere.
- The theory of plate tectonics is supported by geographical evidence such as the formation of mountains, magnetic striping, GPS monitoring of tectonic plate movement and radiometric dating of rocks.
- Similarities in fossil records on different continents can be used as biological evidence in support of the theory of plate tectonics.
- The interactions of tectonic plates at the plate boundaries create physical phenomena such as mountain ranges, volcanic arcs and earthquakes.
- Seismic data is collected in a global network and shared between governments to produce tsunami alerts.
- The impacts of geological hazards such as earthquakes and tsunamis are managed in various ways such as building techniques, and international collaboration between international organisations and governments in the Asia–Pacific region.

Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

Remember

1 Seismic vibrations have been recorded as shown below.



a Name the instrument used to detect and record seismic waves.
b Identify the type of seismic wave indicated by A, B and C on the seismogram.
c The information from seismograms is used to determine which scale of measurement for earthquakes?

2 Define the following terms.

a subduction
b viscosity
c slab pull
d epicentre

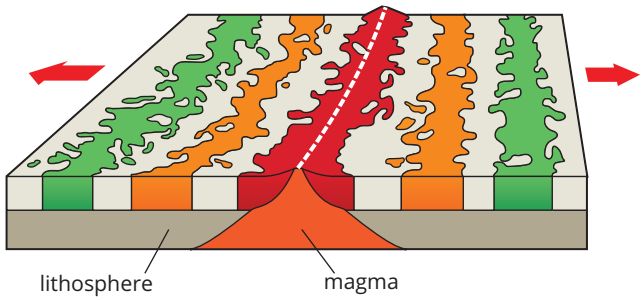
3 Recall one way in which the fossil record contributes to the body of evidence in support of the theory of plate tectonics.

4 State two ways in which the Australian government collaborates with its Asia–Pacific neighbours to reduce risks caused by earthquakes and tsunamis.

Understand

5 Explain why it is possible for Australia to experience earthquakes.

6 Refer to the diagram below.



- **a** Identify the type of geographical evidence for the theory of plate tectonics illustrated by the colours in this diagram.
- **b** State which of the bands represents the rocks that are the youngest. Identify a technique that can be used to establish that these rocks are the youngest.
- **c** Identify the type of plate boundary that is shown in this diagram.
- **d** Name two processes that are occurring as the oceanic crust moves away from the mid-ocean ridge in both directions.
- **e** Would earthquakes be expected to occur along this boundary?
- **f** Name two geological features that can form at a convergent plate boundary.

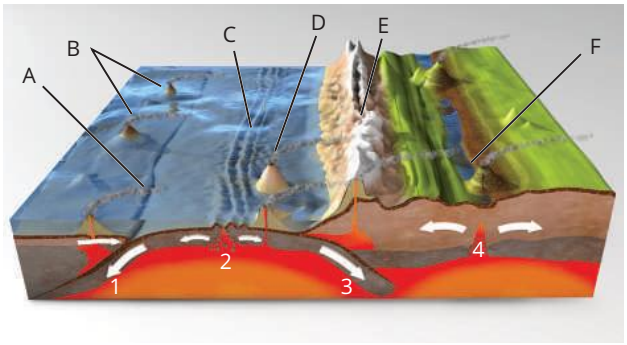
7 Imagine a large undersea earthquake has just occurred near Tonga in the Pacific Ocean. The distance from the epicentre to Byron Bay on Australia's east coast is 3200 km. A tsunami travels at 800 km/h in the open ocean.

- **a** Name one international organisation that monitors seismic data in the Pacific Ocean.
- **b** Calculate how long it will take the tsunami to reach Byron Bay as it travels across open ocean.
- **c** Which Australian government authorities will be responsible for analysing the data to determine if a tsunami warning should be issued for Australia's east coast?

Apply

8 Compare the formation processes of the Himalayas and the Mariana Trench.

9 Consider the figure below, which shows geological features and processes as a result of tectonic plate movement.



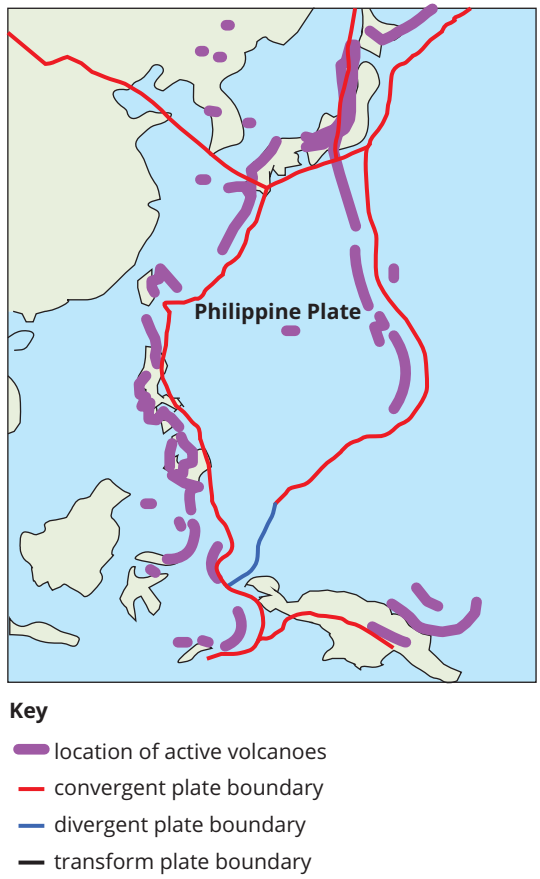
- **a** Use the terms from the list below to identify each of the geological features labelled A–F on the figure.

  fold mountains and volcanoes
  hot spot volcano
  mid-ocean ridge
  rift valley and volcanoes
  trench
  volcanic island arc
- **b** For labels 1–4 on the figure, determine the type of tectonic plate interaction occurring, and the types of crust involved.
- **c** Explain why subduction is occurring at 3 on the figure.

10 Since the Great Tohoku earthquake and tsunami, Japan has constructed 400 km of anti-tsunami barriers and walls along its east coast. Hypothesise why the country made this decision.

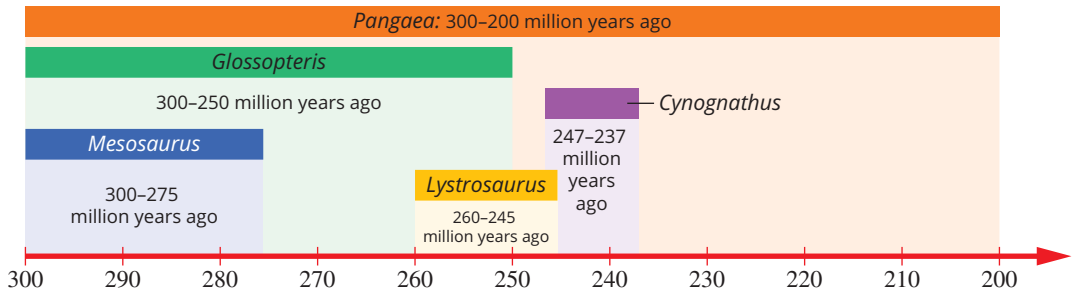
Analyse

11 The map shows the location of active volcanoes.



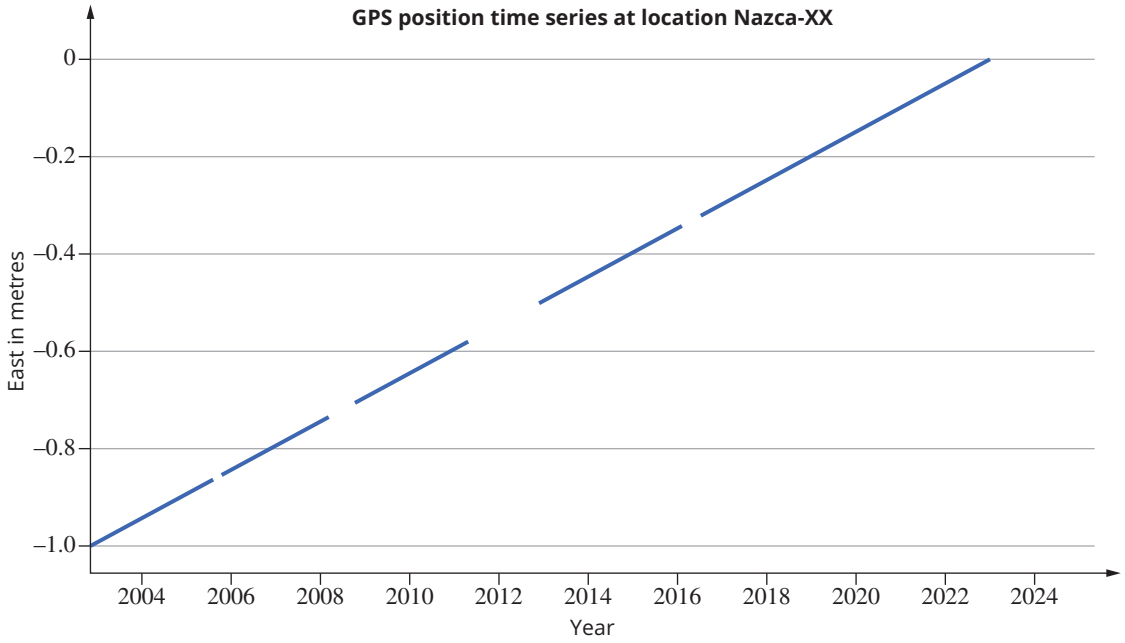
- **a** Identify the type of boundary represented by the red line.
- **b** Describe the distribution of volcanoes.
- **c** Explain why an active volcano is found in the middle of the Philippine Plate.
- **d** Identify the major plates to the east and west of the Philippine Plate.

12 Fossils of four types of organisms have been identified as biological evidence supporting the theory of plate tectonics. These are the seed fern *Glossopteris*, and the reptiles *Mesosaurus*, *Cynognathus* and *Lystrosaurus*. The timeline below shows the periods of their existence and how this aligns with the existence of the supercontinent Pangaea.



- **a** Name the organism that had the longest period of existence in Pangaea.
- **b** Name the organism that had the shortest period of existence.
- **c** Identify the organisms that occurred at the same time as *Glossopteris*.
- **d** Determine which reptiles existed at the same time as each other.
- **e** The Permian–Triassic extinction event occurred about 252 million years ago. State the organisms that appear to have become extinct at, or shortly after, this time.

13 GPS monitoring has been undertaken between 2003 and 2022 at a particular location on an island on the Nazca Plate in the Pacific Ocean. A graph has been produced to model the plate's movement east–west. An upward slope indicates movement to the east. A downward slope indicates movement to the west.



a Propose an investigable question for which this data can provide an answer.

b Is the Nazca Plate moving east or west at location Nazca-XX?

c Approximately how far has the plate moved at this location between 2003 and 2023?

d Calculate the approximate average speed of the plate per year for the period between 2003 and 2023.

e How does this data support the theory of plate tectonics?

HINT

Use the formula

$$\text{average speed} = \frac{\text{distance}}{\text{time}}$$

and convert the distance to centimetres.

Extension: Interpreting data

14 Your task is to use live data to determine the locations of higher magnitude seismic activity in the world in the last 30 days. You will then compare your findings with the locations of the Great earthquakes (earthquakes of magnitude 8.0 M_W and above) on the map on the following page to determine if there is a correlation.

a Go to one of the following sites that show live earthquake data and investigate current seismic activity in the world. Select settings that look at earthquakes of magnitude 4.5 or more for the last 30 days.

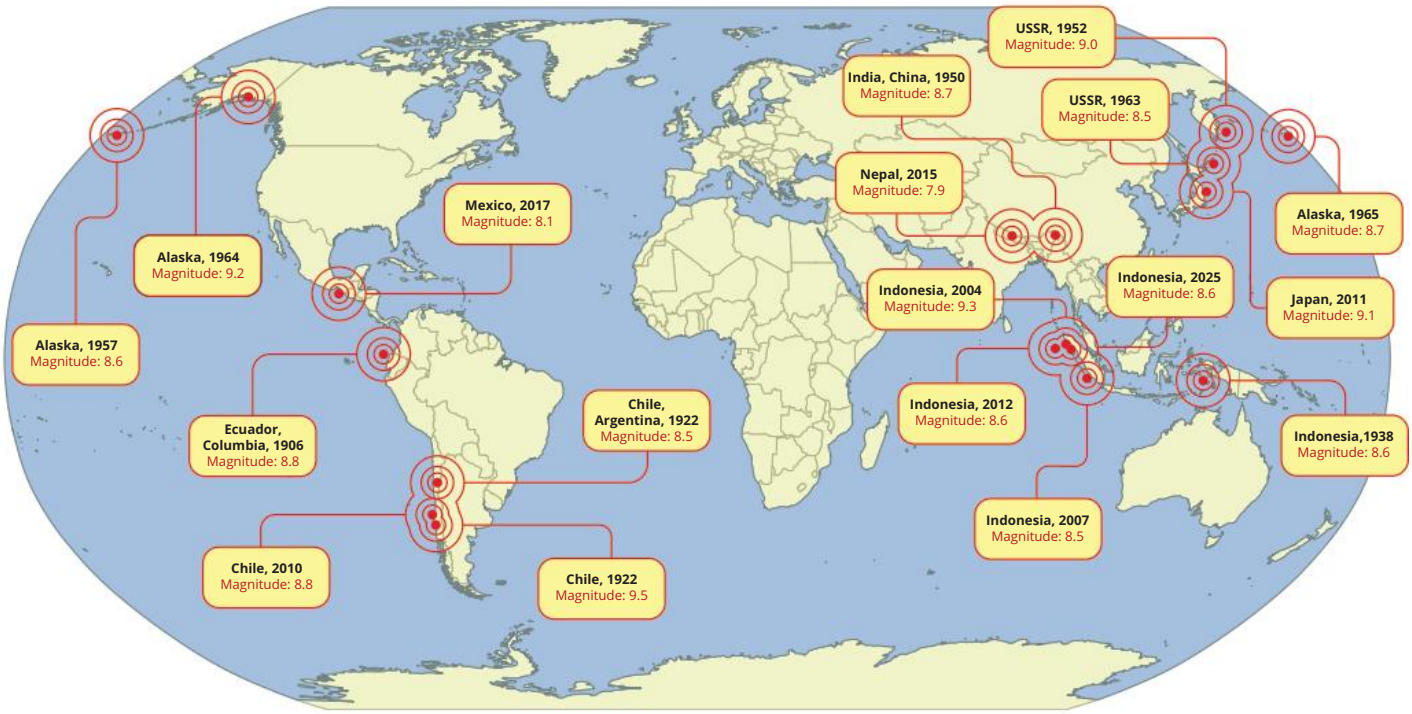
- Geoscience Australia Earthquakes
- Unites States Geological Survey (USGS)
- ArcGIS Online Live Earthquakes and World Volcanoes

b Write a paragraph to describe where most of the earthquakes are concentrated. Use the names of tectonic plates in your descriptions.

c Refer to the map below, which shows the largest earthquakes of the twentieth and twenty-first centuries. Consider the following questions to work out if there is a correlation between the Great earthquakes and current seismic activity.

- Did the Great earthquakes occur where earthquakes are currently concentrated?
- Are there any Great earthquakes that occurred outside of current areas of concentration?
- Are there any current areas of concentration that are not included on the map of Great earthquakes?
- Are there tectonic plates or particular plate boundaries with more than their fair share of Great earthquakes?

d Write a second paragraph to describe the correlation between Great earthquakes and current seismic activity. Also indicate if there are any tectonic plates or plate boundaries that appear to be particularly active in the generation of Great earthquakes.



Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any particular areas that you are confident in, and others where you are not so sure.

6 Glossary

asthenosphere the layer of Earth near the top of the mantle, just below the solid lithosphere, and containing rock that can move very slowly

biosphere the place where all life exists; consists of Earth's surface and its atmosphere

continental crust the crust that forms the continents

convection the transfer of heat through movement in a liquid or gas

convergent boundary a tectonic plate boundary where plates are colliding with each other

divergent boundary a tectonic plate boundary where plates are moving apart from each other in opposite directions

earthquake the rapid movement of the ground, usually back and forth and up and down in a wave motion, due to the movement of tectonic plates

epicentre the point on Earth's surface directly above the focus of an earthquake

focus the place below ground where an earthquake starts

fold mountains mountains formed by crust crumpling upwards as plates collide

force a push, pull or a twist that can change an object's motion

fossil record a list showing the classification of all the species on Earth that have been found as fossils

fossil the preserved remains of a once-living organism

geology the study of Earth

geosphere all the rocks, minerals and landforms that make up Earth

hot spot an isolated place away from plate boundaries where a lot of hot magma collects

intensity a measure of the effect of something

intraplate earthquake an earthquake that occurs away from a plate boundary

lithosphere the crust and the upper mantle together; Earth's tectonic plates

magma molten rock that does not reach Earth's surface

magnetic striping patterns of magnetism trapped in rocks on each side of plate boundaries

magnitude a measure of the size or strength of something

mid-ocean ridge a mountain system on the floor of the ocean

oceanic crust the crust that forms the ocean floor

pitch a tar-like substance that is semi-liquid when hot and becomes hard when cold

radiometric dating a technique for determining the age of rocks that measures the radioactive elements in a substance

ridge push older crust pushed before new ocean crust at mid-ocean ridges, forcing plates apart

rift valley a low-lying valley created by the action of a geological rift or split, often at a diverging plate margin

seismic data data about movements of the ground that is used by scientists to study and monitor earthquakes

seismic wave the shaking, wave-like movement of the ground in an earthquake

seismogram the recorded information from a seismograph

seismograph a seismometer that is connected to a recording device

seismometer an instrument that detects the seismic waves from an earthquake

slab pull a pulling force exerted by older colder and denser oceanic plates sinking into the asthenosphere due to gravity, dragging the rest of the plate with it

subduction when one plate sinks below another plate during a collision

supercontinent one of several large landmasses that are thought to have divided to form present-day continents

tectonic plate a section of Earth's lithosphere that moves about on Earth's surface

theory of plate tectonics the scientific theory that describes the existence and motion of tectonic plates

transform boundary a tectonic plate boundary where plates are sliding past each other either in opposite directions or in the same direction but at different speeds

trench a depression in the ocean floor

tsunami a large and destructive ocean wave or series of waves caused by either a large earthquake on the seafloor, a landslide or a volcanic eruption

tsunami alert a public alert issued by governments to warn vulnerable coastal communities about the potential threat of tsunami

viscosity the measure of a liquid's resistance to flow

volcano a place where extremely hot material from inside Earth erupts at the surface

TOPIC 7

Energy types in systems

Energy is all around you. Using a computer, riding in a car, or kicking a ball—all these interactions involve transfers of energy.

When a collection of objects, materials or processes interact with each other, the result is a system. Often the interactions that allow systems to work involve energy moving (transferring) from one component to another, or energy changing (transforming) from one type to another.

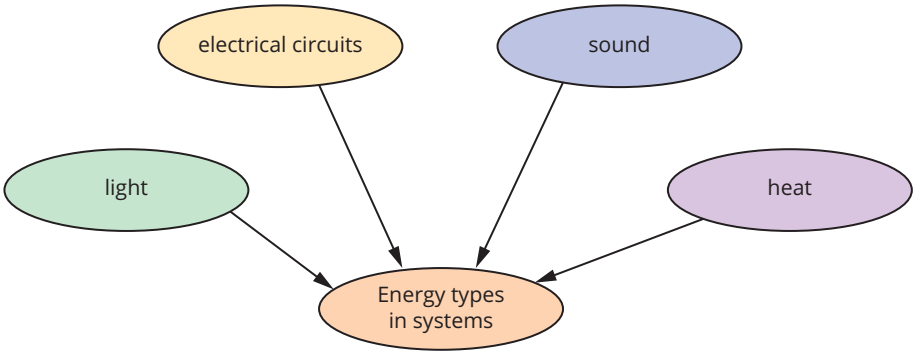
In this topic, you will learn about kinetic and potential energy, transfers and transformations of energy, and how energy is used in society.

Learning intentions

- ☐ To be able to demonstrate how energy can be transferred from one object to another **335**
- ☐ To understand the different categories of kinetic energy **337**
- ☐ To be able to investigate how collaboration between Swami Vivekananda and Nikola Tesla led to an exploration of the relationship between mass and energy **341**
- ☐ To be able to investigate the concept of efficiency **343**
- ☐ To understand the processes involved in the transfer of heat energy **345**
- ☐ To be able to investigate the transfer of heat energy **350**
- ☐ To understand that energy transfers and transformations are required for the success or sustainability of a system **352**
- ☐ To analyse observed energy transformations **356**
- ☐ To be able to demonstrate how chemical potential energy can be converted to electrical energy by constructing an electrical system powered by batteries **358**
- ☐ To understand ways that First Nations Australians use knowledge of energy in traditional fire-starting methods **360**
- ☐ To be able to design, create and report on a system that solves a problem using energy transfer and transformation **364**
- ☐ To understand how the development of sustainable energy in vehicles has had an impact on the environment **366**

7 Energy types in systems

The key concepts that you will use in this topic:



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

Electrical circuits

1 In electrical circuits, there are parts called conductors and insulators. Contrast the properties of electrical conductors and insulators.

2 A simple circuit requires a minimum of three components. Name these components.

Light

3 Describe the process that creates multiple shadows of a player standing in a sport stadium during a game at night.

Sound

4 Describe how an echo can be used to determine the distance to an object.

5 Almost all musical instruments work by creating a vibration. Select a musical instrument and describe how it produces vibrations to create a musical note.

Heat

6 Describe what happens when a warmer object is brought into contact with a colder object.

7 Describe why it feels cold standing on a tiled floor compared to carpet.

7.1 Transfer of kinetic energy

Introduction

Energy is everywhere. Wherever things are changing, energy is at work. One of the most obvious signs of energy is movement. Moving objects have energy and this energy can be transferred from one object to another. Energy is transferred between moving objects, particularly in situations involving collisions and within various types of machines.

In this practical investigation, you will learn about the energy of moving objects and how this energy can be transferred.

Learning intention

To be able to demonstrate how energy can be transferred from one object to another

Success criteria

SC 1: I can list real-life examples in which kinetic energy has been transferred from one object to another.

SC 2: I can investigate ways that kinetic energy can be transferred from one object to another.

SC 3: I can explain why not all energy is transferred from one object to another.

Background

Kinetic energy is the energy associated with motion. Like all forms of energy, it can be transferred between objects. One way in which kinetic energy can be transferred is through a collision.

Collisions are not the only way that kinetic energy can be transferred from one object to another. Many machines are designed to transfer kinetic energy. For example, riding a bicycle (Figure 7.1.1) involves several kinetic energy transfers. As the cyclist pushes on the pedals, they transfer energy to the pedals, causing them to turn. The kinetic energy from the pedals is transferred through the crank, along the chain, and into the sprocket to rotate the wheel.



FIGURE 7.1.1 Energy of motion, or kinetic energy, is transferred from the cyclist to the bicycle wheels, causing the bicycle to move.

Newton's cradle

Newton's cradle is a toy that is a useful tool for demonstrating the way kinetic energy can be transferred between objects. A simple way to use Newton's cradle is to raise the ball at the left side of the cradle (Figure 7.1.2a) and release it. It will swing down to strike the next ball and transfer its kinetic energy to it. The kinetic energy is then transferred through the remaining balls to the ball on the right which swings up into the air (Figure 7.1.2b). This transfer of kinetic energy then repeats in reverse.

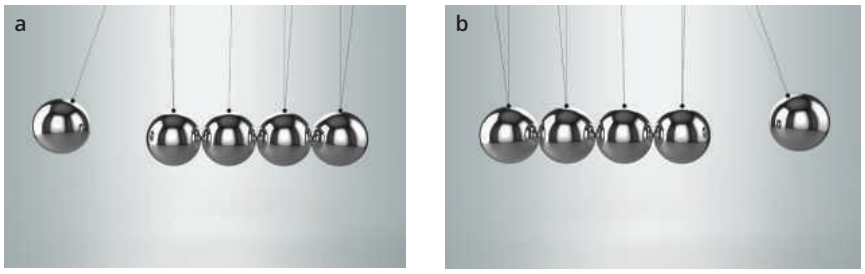


FIGURE 7.1.2 In Newton's cradle one incoming ball (a) collides with the stack, causing a single ball (b) to rebound; this cycle repeats, demonstrating the transfer of kinetic energy between objects.

KEY TERMS

kinetic energy energy possessed by a moving object
Newton's cradle a device that demonstrates the transfer of kinetic energy through a series of swinging spheres

Energy is never lost in an interaction. When energy is transferred between objects, it may appear that energy is being 'used up'. Instead, some energy is often wasted or lost to the surroundings as heat, sound, or other less useful forms: it may help to think about energy being 'traded' for a different form of energy.

In the following investigation, you will explore several different scenarios of energy transfers using Newton's cradle.

Aim

To investigate how kinetic energy is transferred in Newton's cradle

GO TO
Toolkit section 1.2, Making predictions from observations

Prediction

Write predictions for your investigation. Copy the following table in your notebook. Complete the 'Starting condition' and 'Predicted outcome' columns of the table to identify what starting conditions you will use and what you expect to happen. The first row has been completed for you as an example.

Starting condition	Predicted outcome	Observed outcome
Raise one ball on the left.	One ball on the right will move.	

Materials

- Newton's cradle

Method

1. Observe the outcomes for each of the starting conditions listed in your table.
2. Observe what happens to the balls if they are left to keep colliding for a long time.

Results

1. Complete the table with your results.
2. Describe what happens to the balls over time if they are left to keep colliding.

Evaluation

1. List some examples of kinetic energy transfers in a:
   a. football match
   b. pinball machine.
2. In Newton's cradle, how is kinetic energy transferred between the balls?
3. Describe what happens to the balls in Newton's cradle if they are left to bounce for a long period of time.
4. If energy is never lost, but can transform from one form of energy to another, explain your answer for question 3.

7.2 Types of kinetic energy and particles

Lesson overview

Kinetic energy is the energy associated with moving objects. When a large object, such as a car or a cricket bat, is in motion, its kinetic energy is easy to observe—it is clear how these objects can cause changes to others, particularly through collisions. However, some objects, like electrons or atoms, are too small to be seen. Nevertheless, when these objects move, they also have kinetic energy. This energy is transferred to other forms, such as heat energy, sound energy, or the energy carried by an electric current.



FIGURE 7.2.1 (a) A guitar transforms kinetic energy of vibrating strings into sound; (b) stored electrical energy in devices is transformed into light in the display, sound in the speakers, and electromagnetic energy for wireless communication; (c) a fire transforms chemical energy into heat energy and light.

Learning intention

To understand the different categories of kinetic energy

Success criteria

SC 1: I can explain why heat, sound and electricity can be described as forms of kinetic energy.

SC 2: I can describe everyday systems that involve changes between movement, heat and electricity.

SC 3: I can explain how the particle model can be used to demonstrate changes in heat energy.

SC 1 I can explain why heat, sound and electricity can be described as forms of kinetic energy

Heat, **sound** and electricity can all be described in terms of kinetic energy.

Heat energy moves from warmer to cooler substances. When a substance is heated, the particles it is made of (atoms or molecules) start to move faster (Figure 7.2.2).

KEY TERMS

heat a form of energy that moves from a warmer object or substance to a cooler object or substance

sound a form of energy that travels as vibrating waves and can be heard by the ears as sound

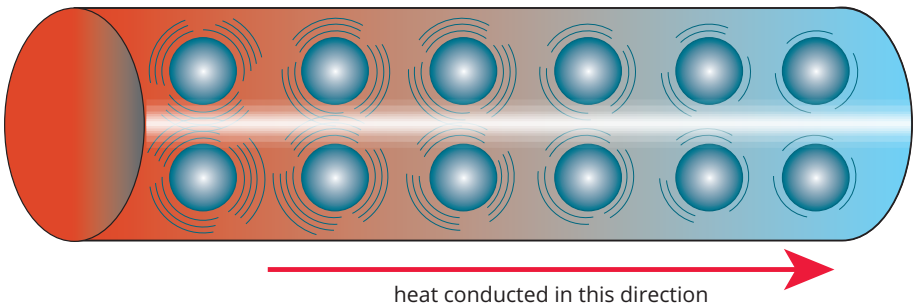


FIGURE 7.2.2 The end of the object at a higher temperature contains particles that are vibrating more than the particles in the end at a lower temperature.

Sound travels as waves and is heard by the ears. Sound travels by vibrating particles. For example, when you hear music from a speaker (Figure 7.2.3), the movement of the speaker causes nearby air particles to vibrate. The kinetic energy of the vibrating air particles then transfers through the air where your ear interprets it as sound.

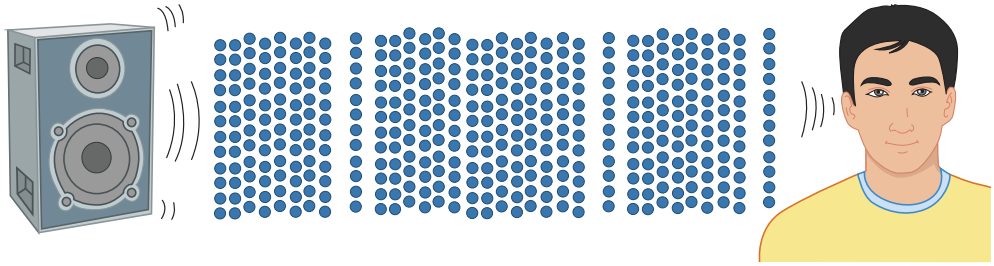


FIGURE 7.2.3 A particle drawing used to show the vibration and movement of sound

Electric current in a circuit is the motion of **electrons** through a wire (Figure 7.2.4). Electrons are small negatively charged particles that are present in all atoms. The kinetic energy of the moving electrons is observed as electricity.

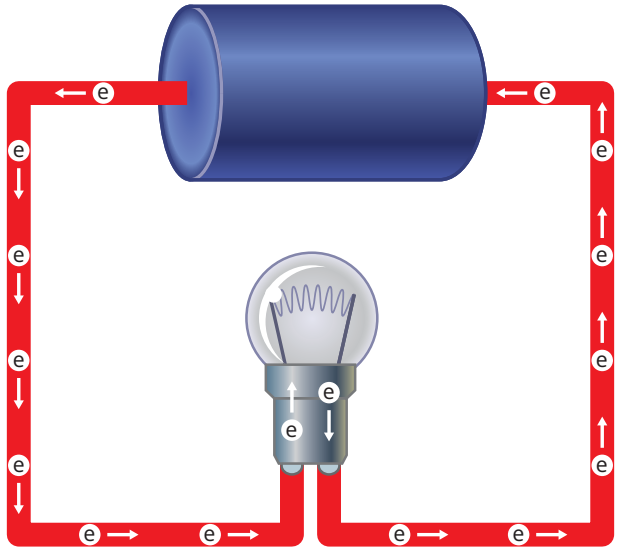


FIGURE 7.2.4 The pathway of electrons through an electric circuit

For the three types of energy listed in this section, there is some sort of movement occurring; that is, each can be described as a form of kinetic energy.

SC 1 CHECK YOUR UNDERSTANDING

Explain why heat could be described as a form of kinetic energy.

KEY TERMS

electric current the flow of charged particles (electrons) through a conductor

electron negatively charged subatomic particle, located around the nucleus of an atom

Scifile

Domino effect

When you knock over the first domino in a line, it transfers its kinetic energy to the next one, causing a noisy chain reaction as they fall. This simple example demonstrates the transfer of kinetic energy and transformation into sound energy.



SC 2 I can describe everyday systems that involve changes between movement, heat and electricity

When you rub your hands together, they heat up. This is an example of an **energy transformation**. The kinetic energy of your hands transforms into the heat energy you feel. Another example of kinetic energy transforming to heat energy is in the striking of a match (Figure 7.2.5). The kinetic energy of the match across the striking surface transforms into heat energy, which is required to set the match alight.

You can see the transformation of kinetic to electrical energy in a wind turbine (Figure 7.2.6). The motion of the wind causes the movement of the blades on a wind turbine. The turning blades produce electric current.



FIGURE 7.2.5 Energy transformation: movement → heat



FIGURE 7.2.6 Energy transformation: movement → electrical energy

SC 2 CHECK YOUR UNDERSTANDING

Provide an example of each of the following types of energy transformation.

a electrical → kinetic

b heat → kinetic

c electrical → heat

KEY TERMS

energy transformation the conversion of energy from one form to another, such as the conversion of potential energy into kinetic energy as an object falls

particle model a model used to help describe and explain the behaviour of particles in solids, liquids and gases

SC 3 I can explain how the particle model can be used to demonstrate changes in heat energy

To understand how heat energy affects a substance, imagine that all the particles in a substance are modelled as tiny balls. This is known as the **particle model** (Figure 7.2.7).

In a solid, the particles are all tightly packed together so that they can only vibrate in their positions.

In a liquid, the particles are still packed together but can move about.

In a gas, the particles are free to move. They may bump into each other or into the walls of their container.

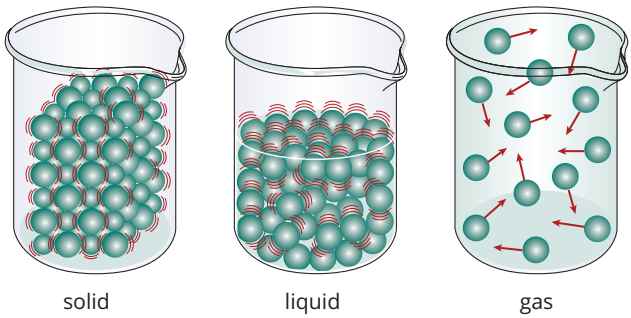


FIGURE 7.2.7 Three phases of matter represented with the particle model

Heating

When a material is heated, the kinetic energy of its particles increases, making them move faster. As the particles speed up, they spread out, causing the material to expand (Figure 7.2.8).

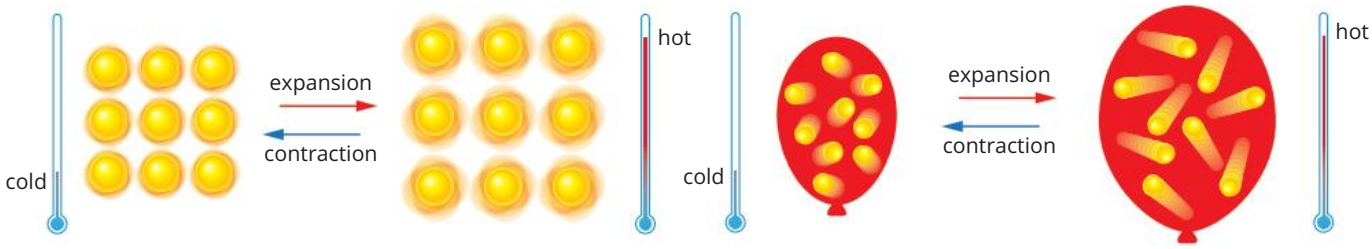


FIGURE 7.2.8 Increased temperature causes materials, including solids and gases, to expand.

KEY TERM

temperature a measure of the average kinetic energy of particles in a substance that indicates how hot or cold the substance is

Heat versus temperature

In physics, heat and **temperature** describe two different things. Heat describes energy, which transfers from a hotter object to a colder object. Temperature describes the average motion (kinetic energy) of all the particles within an object.

Imagine two saucepans filled with boiling water at 100°C, but one holds more water than the other (Figure 7.2.9). The individual particles in both saucepans are vibrating, on average, with the same amount of energy, since they are at the same temperature. However, the saucepan with more water contains more total energy because it has a greater number of particles.

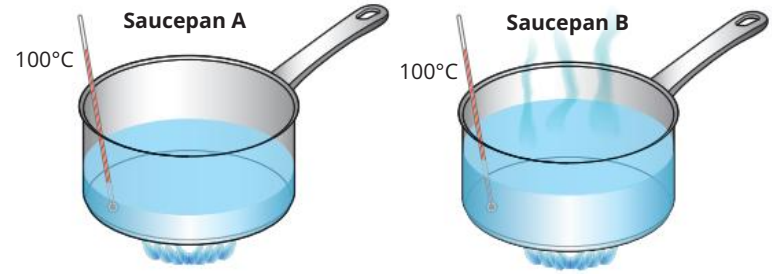


FIGURE 7.2.9 Both saucepans are at a temperature of 100°C, but saucepan B has more total energy because it contains a greater mass of water.

SC 3 CHECK YOUR UNDERSTANDING

Use the particle model to describe what happens when a substance experiences an increase in temperature.

Lesson review

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

1. Identify a scenario that involves energy transformation between heat, electrical and kinetic energies.
2. Describe how an electric current demonstrates kinetic energy in a circuit.
3. Compare heat energy and sound as forms of kinetic energy.
4. Use the particle model to explain the differences in particle movement between a solid, liquid and gas when heated.

7.3 Influence of cultural perspectives on world views

Introduction

Swami Vivekananda was an Indian monk, philosopher and spiritual leader. Nikola Tesla was a Serbian-American inventor, electrical engineer and physicist. Despite coming from different backgrounds and fields of study, they shared a passion for understanding the mysteries of the universe. Together, they conducted experiments and engaged in deep conversations on the nature of energy and matter.

In this inquiry activity, you will investigate how collaboration between Swami Vivekananda and Nikola Tesla, shown in Figure 7.3.1, led to an exploration of the relationship between mass and energy.

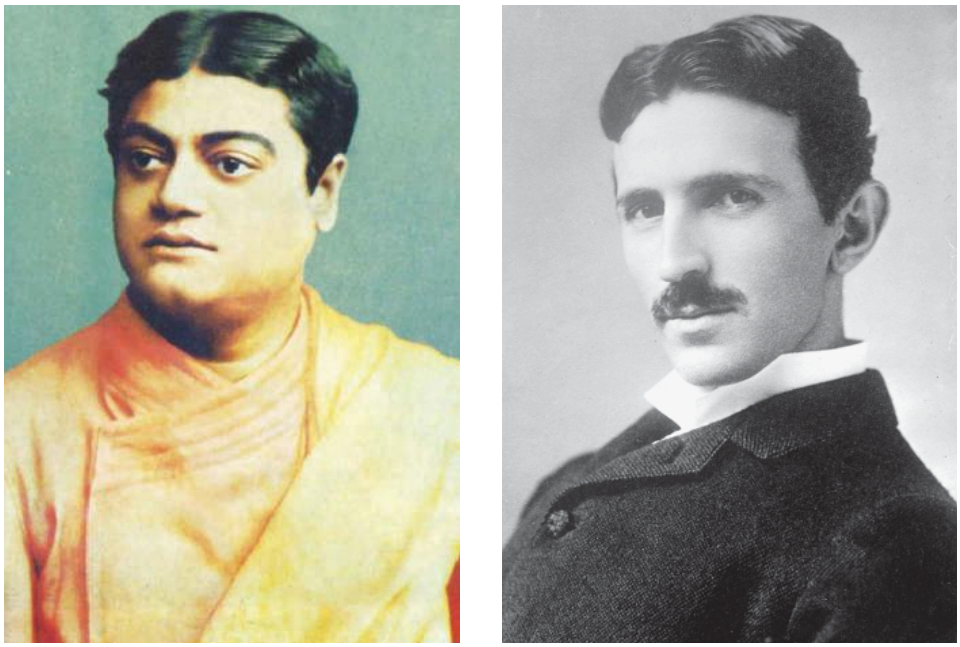


FIGURE 7.3.1 Despite different cultural backgrounds, Swami Vivekananda (left) and Nikola Tesla (right) shared a passion for exploring the nature of energy.

Background

Swami Vivekananda and Nikola Tesla both believed that the physical world was deeply interconnected, and that energy and matter were different expressions of the same thing.

Their collaboration led to some ground-breaking discoveries, including the understanding that mass and energy are interchangeable, as expressed in Einstein's famous equation $E = mc^2$. This idea enhanced understanding of the universe and opened up new possibilities for using energy in innovative ways.

Learning intention

To be able to investigate how collaboration between Swami Vivekananda and Nikola Tesla led to an exploration of the relationship between mass and energy

Success criteria

SC 1: I can describe the relationship between Swami Vivekananda and Nikola Tesla and how it led to exploration around mass and energy.

SC 2: I can explain how cultural perspectives and world views influenced the development of scientific knowledge.

SC 3: I can collaborate to create a presentation that describes how cultural perspectives can influence the development of science.

HINT

Terminology tip

Note that all matter has mass, and mass is used as a measure of the amount of matter.

Aim

To investigate how collaboration between Swami Vivekananda and Nikola Tesla led to an exploration of the relationship between mass and energy

Plan

Investigate more about the background of Swami Vivekananda and Nikola Tesla.

1. Investigate how Swami Vivekananda and Nikola Tesla first met and how it led to their shared exploration into mass and energy.
2. What was one of the first key ideas they explored?

Design

GO TO
Toolkit section 5.1, Methods for presenting scientific ideas

Consider the broader context for how collaboration and communication can influence the development of scientific knowledge.

1. What did Swami Vivekananda and Nikola Tesla's discussions and experiments lead to?
2. Investigate how cultural perspectives and world views influenced the development of this scientific knowledge.
3. Using the example of Vivekananda and Tesla, consider how you could create a presentation that describes how cultural perspectives can influence scientific knowledge. You should think about the following: What platform will you use? How could you work as part of a team? What key headings could you include?

Conduct

In your team/group, combine the research from your planning and designing to create a presentation. Your presentation should describe how cultural perspectives can influence the development of science using Vivekananda and Tesla as an example.

Improve

Suggest three improvements to your presentation. For example, how would you change any key headings or the platform you used to present this information?

Evaluate

1. What did you learn about the influence of cultural perspectives in this inquiry activity?
2. What skills did you use in this inquiry activity?

7.4 Efficiency of energy transformations

Introduction

When a ball is dropped, its gravitational potential energy transforms to kinetic energy (movement). When the ball hits the floor and bounces, some of its kinetic energy is transformed back to gravitational potential energy, while some is 'lost' to the surroundings as sound and heat. This process continues until all its energy has been 'lost' into the surroundings (Figure 7.4.1).

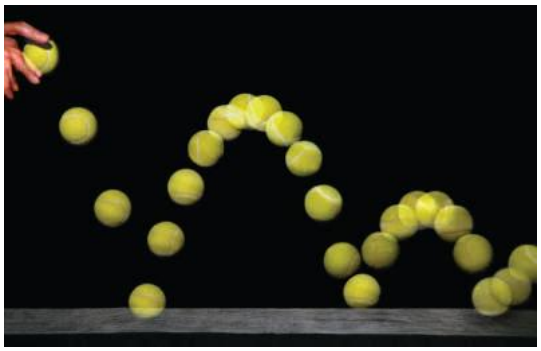


FIGURE 7.4.1 Overlaid frames of a video showing a bouncing tennis ball

Efficiency is a percentage describing how much transformed energy is useful energy. In the case of the bouncing ball, the sound and heat are not useful forms of energy, so the efficiency is less than 100%.

In this practical investigation, you will explore the efficiency of a bouncing ball.

Learning intention

To be able to investigate the concept of efficiency

Success criteria

SC 1: I can describe the concept of efficiency.

SC 2: I can select appropriate equipment to design an experiment that investigates the efficiency of the transfer of kinetic energy.

SC 3: I can identify sources of error in an experiment.

Background

Kinetic energy is the energy of movement. **Potential energy** describes energy that is stored by an object because of its position or structure. There are different types of potential energy. The one referred to in this practical investigation is gravitational potential energy. **Gravitational potential energy** is the energy stored by an object because of its position above the ground.

During most energy transformations, some energy is transformed into energy that is not useful for the **system**. For example, when you bounce a ball, some of the energy is transformed into heat and sound. This can make it seem as though energy is being lost, but energy is always conserved (maintained) in transformations.

The **efficiency** of an energy transformation describes the amount of energy transformed that is useful. So, in the case of the bouncing ball, the efficiency describes how much energy is staying in the system to keep the ball bouncing. In a perfectly efficient system (100% efficient), the ball would continue to bounce forever.

The efficiency of a bouncing ball is calculated with the following equation:

$$\text{efficiency} = \frac{\text{rebound height of first bounce}}{\text{initial height above ground}} \times 100\%$$

KEY TERMS

potential energy energy stored by an object (because of its position or chemical structure) that can be transformed into another form of energy

gravitational potential energy energy stored by an object because of its position above the ground

system a collection of interacting components that form an integrated whole

efficiency a measure of the useful energy output of an energy transfer

Aim

To calculate and compare the efficiency of bouncing balls

Prediction

Which type of ball do you think will be the most efficient and will rebound to greater heights when dropped—a table tennis ball, a squash ball, a hi-bounce rubber ball or some other type?

SAFETY NOTE

- Write some safety notes for your investigation.

Materials

Write a materials list for your investigation.

Assessment of risk

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

HINT

If you use a video camera to record bounces, it can be difficult to read the markings on the metre ruler. Put masking tape around each 10 cm distance as this will show up clearly on the video.

Method

Write a method for your investigation.

Results

Create a table to record your results, including space to write the drop height. Some column headings you might include are: ball type, rebound height, efficiency, average efficiency.

Conclusion

Write a conclusion for your investigation.

1. Assess whether your predictions are supported by your results or not.
2. Identify sources of error in your investigation. How did you work to minimise them?

Evaluation

1. What are the strengths and weaknesses of the method you used in this investigation? Choose two other groups from your class. Evaluate the method they used. What can you learn from what they did?
2. How could your method be improved? Include a reference to the precision of the data obtained.
3. Squash balls get very hot after a short time in play. Use your results from this investigation to explain why.
4. List the balls in order from the one you predict will be the hottest after a bounce to the one that will be the coolest.
5. Is the investigation that you have produced a reproducible investigation?

GO TO

Toolkit sections 1.2, Making predictions from observations, 4.1, Evaluating precision and 2.2, Reproducible investigations.

7.5 Transfer of heat energy

Lesson overview

Heat energy is the kinetic energy that moves from warmer to cooler substances. There are three methods of heat transfer: conduction, convection and radiation.

In this lesson you will learn about the different methods of heat transfer and how they are used in everyday life.

SC 1 I can list the three different ways heat energy is transferred

Heat moves from areas of high temperature to low temperature when it is transferred. There are three processes involved in the transfer of heat energy.

Conduction

Conduction is the process of heat transfer by the direct contact of particles in a solid, where heat energy is passed from particle to particle.

For example, the metal of the pan conducts heat easily, but the wooden handle does not (Figure 7.5.1).

Convection

Convection is the process of heat transfer by the movement of a liquid or gas.

For example, as the water at the bottom of a pot heats up, the particles in the water speed up and spread out. The warm water at the bottom is therefore less dense than the cooler water above. This causes a current to form where the warm water rises to the top and the cooler, denser water sinks to the bottom (Figure 7.5.2).

Radiation

Radiation is the process of heat transfer by electromagnetic waves.

Electromagnetic radiation describes quickly moving invisible waves. Unlike other forms of waves, such as sound, electromagnetic radiation does not require a substance to travel through, allowing it to travel through a vacuum. An example of a device that uses radiation to transfer heat is a microwave oven (Figure 7.5.3).

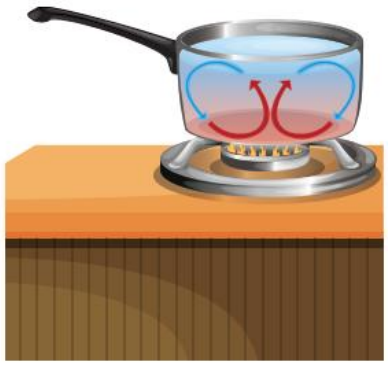


FIGURE 7.5.2 As the water at the bottom of the pot is heated, it rises, creating a convection current.



FIGURE 7.5.3 Food is cooked in a microwave oven by radiation.

Learning intention

To understand the processes involved in the transfer of heat energy

Success criteria

SC 1: I can list the three different ways heat energy is transferred.

SC 2: I can describe what is occurring to the particles during each method of heat transfer.

SC 3: I can describe examples of heat transfer in real life.



FIGURE 7.5.1 The hot pan conducts (transfers) heat to the food it contains.

SC 1 CHECK YOUR UNDERSTANDING

List three different ways heat can be transferred. Provide an example of each.

SC 2 I can describe what is occurring to the particles during each method of heat transfer

Movement of particles during heat transfer

The particle model describes all matter as being made up of small particles that are constantly in motion. When a substance heats up, its particles start to vibrate or move faster. It is the motion of the particles (their kinetic energy) that determines the temperature of the substance.

Particles in conduction

In conduction, heat is transferred through a material or between two objects in contact with each other. Particles in an object are always vibrating. When the object conducts heat, the vibration of the particles increases. These vibrations pass heat energy through the material as shown in Figure 7.5.4.

An example is when you hold a warm drink. The vibration of the particles in the mug transfers heat to your hands via conduction.

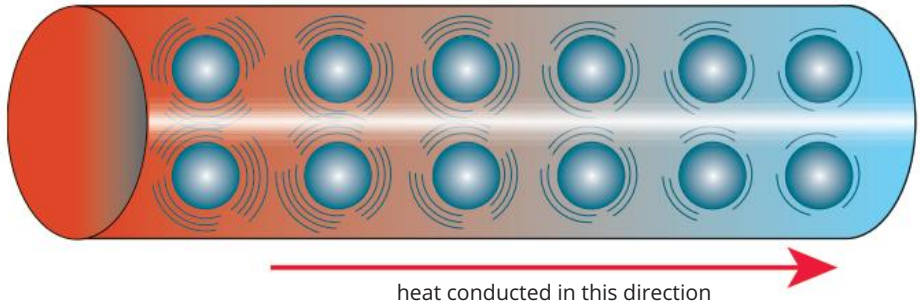


FIGURE 7.5.4 In conduction, particles transfer heat via vibrations.

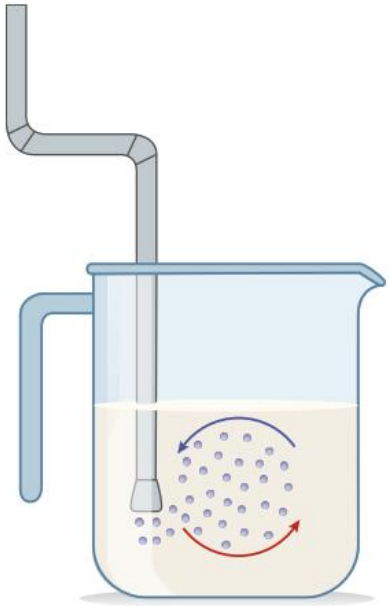


FIGURE 7.5.5 A steam wand is used to heat milk, causing the density of the particles to decrease, creating a convection current.

Particles in convection

In convection, heat is transferred through the movement of particles in a gas or liquid. Convection cannot occur in a solid because the particles in a solid are not free to move around.

An example of heat transfer via convection is a barista frothing milk (Figure 7.5.5). As heat is applied through the steam wand to the milk at the bottom of the jug, the particles start to move faster and spread out. This makes the milk at the bottom less dense. The denser, cooler milk at the top then sinks to the bottom, creating a current.

Convection currents occur whenever there is a change in temperature within a gas or liquid. For example, convection currents can also be seen in weather systems as warmer and cooler air in the atmosphere mix.

Radiation

Radiation is unique compared to conduction and convection because it does not involve the motion of particles.

Radiation is the transfer of heat by electromagnetic radiation. Because this form of heat transfer does not rely on the kinetic energy of particles, it does not require a solid, liquid or gas (unlike conduction and convection).

An example of a heat transfer via radiation is Earth being warmed by the Sun through the vacuum of space (Figure 7.5.6). Even though the Sun is not in contact with Earth, and there is no liquid or gas filling the space between the Sun and Earth, Earth is still warmed by the Sun's electromagnetic waves.

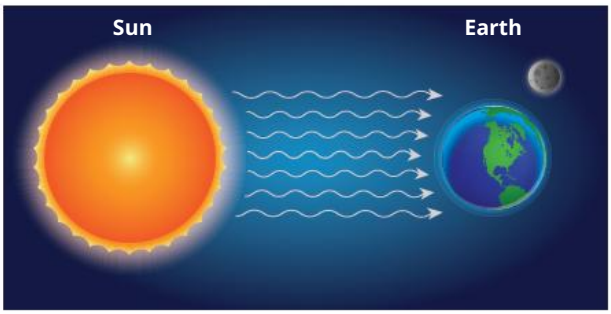


FIGURE 7.5.6 Particles are not required for heat transfer via radiation; this means it can occur in the vacuum of space.

Scifile

Insulation

Insulating your home helps to keep it warm in winter and cool in summer. Insulating materials, packed into the ceiling and walls, slow down the transfer of heat, making your home more energy-efficient.



SC 2 CHECK YOUR UNDERSTANDING

Explain how particles behave differently in conduction, convection and radiation.

SC 3 I can describe examples of heat transfer in real life

The three forms of heat transfer can be seen in many everyday scenarios. A few examples of this are explored below.

Iced drinks

In an iced drink, the drink itself is warmer than the ice. The warmer drink transfers heat to the cold ice via conduction (Figure 7.5.7). The drink cools down as its heat energy moves away and the ice heats up, causing it to melt.

Holding an iced drink can cause it to warm up as heat is transferred from your hands to the drink. This can be prevented by using a cup made from insulating materials.

Some materials are able to conduct heat more easily. These are known as **conductors**. Metals are an example of a conductor. Materials that do not conduct heat very well are known as **insulators**. Some examples of insulators are air, rubber and polystyrene (the foam used in an Esky). Some insulators can completely stop heat transfer from occurring.



FIGURE 7.5.7 Heat is always transferred from a warmer to a cooler substance. So it is more accurate to view this scenario as the drink heating the ice.

KEY TERMS

conductor a material through which heat, sound or electrical energy can be transferred
insulator a material that does not readily allow the transfer of heat, sound or electricity—the opposite of a conductor



FIGURE 7.5.8 A heater uses a combination of radiation and convection to keep you warm.

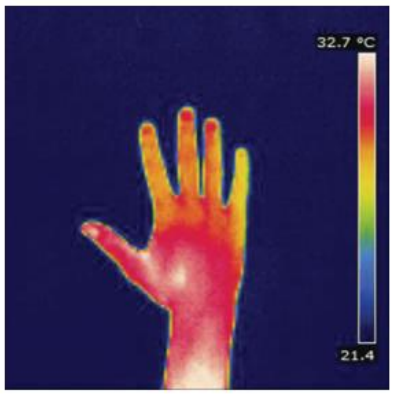


FIGURE 7.5.9 A thermal camera image showing electromagnetic waves emitted from a hand.

Heaters

When a heater is switched on, the air near the heater starts to warm up. These air particles speed up and spread out, making the air nearest the heater less dense. The warm air begins to rise. The cooler, denser air at the top of the room then sinks to the bottom. This creates a convection current, transferring heat throughout the space.

You'll notice in Figure 7.5.8 that the heater is glowing. The glow is a sign that heat is being transferred as electromagnetic radiation. The electromagnetic waves from the heat source travel outwards, warming the person's feet. This is why the person has placed their feet in front of the heater, to be in the path of the radiation to quickly warm their feet. In comparison, convection is a slower process that causes the entire room to become heated over time.

It is important to understand that all objects release some amount of radiation as heat regardless of their temperature, not only hotter objects like the heater. Even human bodies are radiating some heat energy, as shown in the thermal image of a person's hand in Figure 7.5.9.

Cooking

It is important to understand that each method of heat transfer does not usually happen on its own. In some situations, one method of heat transfer might dominate, but often all three are present.

Cooking is a clear example (Figure 7.5.10). Heat is transferred by radiation from the heat source to all nearby objects. For example, if you hold your hand a safe distance from the heat source, it will start to warm up. Heat will transfer by conduction within an object or between objects that are in contact. This is how the heat travels through the saucepan and to the food inside. It is also how heat travels along the handle, especially if it is made from conducting materials. Within liquids inside the saucepan, and the air above it, convection will dominate.

When analysing a scenario, make sure to consider the role of each type of energy transfer—do not quickly assume that only one is present.

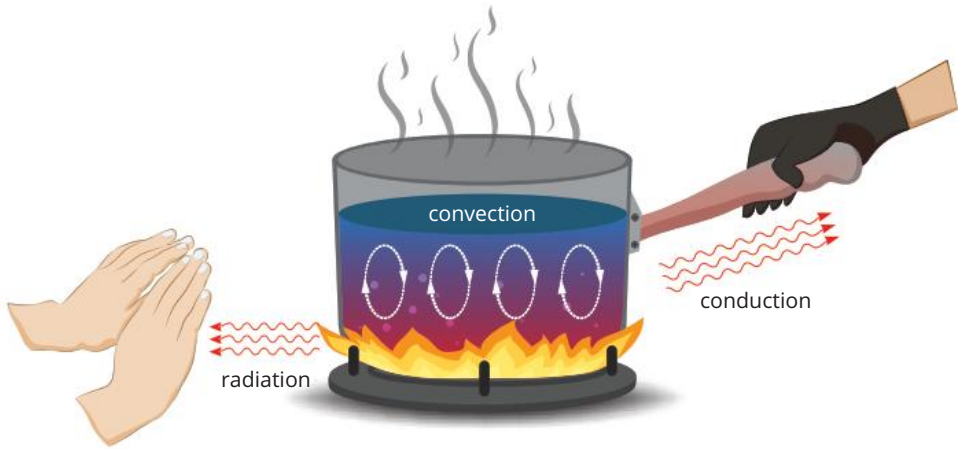


FIGURE 7.5.10 Most systems involve all three methods of heat transfer simultaneously.

SCIENCE IN SOCIETY

Analysing heat transfer data

When scientists investigate heat transfer, they collect data to understand how heat moves from one place to another. For example, they might use a thermal camera to investigate the temperature of machinery as it operates (Figure 7.5.11). By analysing this data, they can develop conclusions about the efficiency and safety of the machinery.



FIGURE 7.5.11 A thermal image of machinery in operation, showing heat distribution

Evaluating the validity of a heat transfer investigation is important to ensure accurate results. Scientists look at factors such as the accuracy of the measurements, the consistency of the data, and whether the experiment was conducted under controlled conditions. This helps them determine if their conclusions are reliable.

In everyday life, this kind of evaluation is used in many industries. For example, in the food industry, companies test how quickly their products heat up or cool down to ensure they are safe and tasty (Figure 7.5.12). Unexpectedly higher temperatures can suggest chemical reactions are occurring in the food, such as increased levels of fermentation. By evaluating their heat transfer investigations, they can improve their processes and create better and safer products.



FIGURE 7.5.12 A food engineer monitors temperature levels.

SC 3 CHECK YOUR UNDERSTANDING

Describe examples of how heat could be transferred by conduction, convection and radiation on a hot day in summer.

Lesson review

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

1. Identify three methods of heat transfer.
2. Consider a metal rod that is being heated at one end.
   a. Sketch the motion of particles inside the metal.
   b. Describe how heat is transferred along the rod by conduction.
3. Explain the process of convection.
4. Provide an example of heat transfer by radiation that has not already been used as an example in this lesson.
5. Consider the heat transfers that occur in a house.
   a. Describe how heat is transferred by conduction in the walls.
   b. Explain how convection contributes to heat transfer in the house.
   c. Identify how radiation plays a role in heating the house.

7.6 Heat conductors and insulators

Learning intention

To be able to investigate the transfer of heat energy

Success criteria

SC 1: I can analyse data collected from an investigation to develop a conclusion.

SC 2: I can evaluate the validity of an investigation into heat transfer.

Introduction

Conduction is the transfer of heat energy through a material. Some materials are good conductors of heat and others are poor conductors. If rapid energy transfer is needed—such as when heating a pan of water—a good conductor should be used. To minimise energy transfer—for example, to prevent burns—a poor conductor is required. Poor conductors, known as insulators, reduce heat transfer to the surroundings.

In this practical investigation, you will study the transfer of heat by comparing the conductivity of different materials.

Background

Some materials are better conductors of heat than others. The rate of conduction is determined by the material's **conductivity**. To keep a hot drink warm, you would choose a cup made from a material that has low conductivity, making it a poor conductor of heat. A poor conductor is a good insulator. A good insulator will transfer minimal heat from the drink to its surroundings due to its low conductivity.

KEY TERM

conductivity a measure of the ability of a material to conduct heat, sound or electrical energy

Aim

To compare how effectively different substances conduct heat

Prediction

GO TO
Toolkit section 1.2, Making predictions from observations

Which material do you think will be the poorest conductor (and best insulator) of heat and keep the water hot for the longest—metal, polystyrene or ceramic? Which will be the best conductor?

Materials

- supply of hot water
- polystyrene cup
- metallic mug
- ceramic coffee mug
- thermometers or temperature probes and data logger
- 100 mL measuring cylinder
- stopwatch/timer

SAFETY NOTE

- Be careful when handling hot liquids to avoid burns.

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. Carefully pour 100 mL of hot water into each cup. Make sure that the water poured into each cup is at the same temperature.
2. Place a temperature probe or thermometer into each cup.
3. Measure the starting temperature using the datalogger or thermometer.
4. Take temperature measurements every minute for 10 minutes. Record the results in a table.

Results

1. Create a table to record your results. The column headings you should include are 'time' and 'temperature'. Ensure you include space in your table for each type of cup.
2. Plot a line graph showing the temperature of the water in the three cups over 10 minutes. Use different colours to plot the lines for each cup tested. Alternatively, use a spreadsheet to plot the line graph for you.

GO TO
Toolkit section 3.2, Creating a line graph using a spreadsheet

Conclusion

Use your results to write a conclusion for your investigation and comment on the accuracy of your prediction.

Evaluation

To be a valid scientific test, the three cups used in this investigation should be the same thickness and have the same diameter opening at the top. Explain why these factors are important.

GO TO
Toolkit sections 4.2, Evaluating validity and 4.3, Evaluating reliability

7.7 Types of energy transformation in systems

Learning intention

To understand that energy transfers and transformations are required for the success or sustainability of a system

Success criteria

SC 1: I can list examples of how types of potential energy (chemical, gravitational and elastic) can be transferred and transformed into kinetic energy.

SC 2: I can explain why not all forms of energy transfer and transformation are useful.

SC 3: I can draw diagrams to demonstrate the transfer and transformation of energy in a range of living and non-living systems.



FIGURE 7.7.1 A kangaroo swiftly hops across the water's surface, transforming elastic potential energy to kinetic energy.

Lesson overview

The two most analysed forms of energy related to motion are kinetic energy and potential energy. Kinetic energy involves movement, such as kicking a ball or the motion of particles, which can be transformed to other forms, such as heat and sound energy.

Potential energy, also known as stored energy, refers to energy an object has due to its position or condition, giving it the potential to cause change. For example, when an archer draws the string of a bow, the stretched string stores elastic potential energy, which is transformed to kinetic energy when released, launching the arrow.

In this lesson, you will learn about the different types of potential energy and the ways in which it can be transformed.

SC 1 I can list examples of how types of potential energy (chemical, gravitational and elastic) can be transferred and transformed into kinetic energy

Types of potential energy

Potential energy describes the energy stored because of an object's position or structure. There are different types of potential energy.

Elastic potential energy is the energy stored in a stretched or compressed material, such as an elastic band.

Gravitational potential energy is the energy stored by an object because of its position above the ground, such as a diver on a diving board. The higher the object, the greater the gravitational potential energy.

Chemical potential energy is the energy stored in substances, such as petrol.

Nuclear potential energy is the energy stored in atoms, such as uranium. This potential energy is utilised in nuclear power plants.

Energy transformations

Energy can be transformed into different forms. One type of potential energy can be transformed into another type of potential energy. In every transformation, energy is always conserved. This means that no energy is lost during a transformation.

Energy transformations are crucial for the survival of many animals. For example, kangaroos use elastic potential energy stored in their leg muscles to hop (Figure 7.7.1). The stored energy is transformed into kinetic energy, allowing them to move quickly and efficiently.

Kinetic energy to elastic potential energy

Resistance bands are large elastic bands commonly used in fitness programs and physiotherapy. The person's movement (kinetic energy) is transformed into the elastic potential energy within the resistance band as it stretches.

If the person lets go of the band while it is stretched, the elastic potential energy would be transformed back into kinetic energy as the band snaps back.



Gravitational potential energy to kinetic energy

Wingsuit flying is an extreme sport, similar to skydiving, where a webbed suit is used to increase time in the air compared to the freefall of skydiving. The surface area of the suit slows down the transformation of gravitational potential energy (due to height) into kinetic energy (movement) as the diver falls.



Chemical potential energy to kinetic energy

In open pit mining, chemical explosives such as dynamite are used to fracture (break) rock to make it easier to excavate. In the explosion, chemical energy stored in the dynamite is transformed into kinetic energy, which fractures and displaces rock. In addition to the useful energy transformation, some is also 'wasted' as heat, light and sound.



SCIENCE IN SOCIETY

Energy transformations in an ecosystem

Food chains show the transfer of energy between organisms. Plants get energy from the Sun, herbivores eat plants and carnivores eat herbivores.

Plants use chloroplasts to transform electromagnetic waves (radiation) from the Sun into chemical energy, which is stored in their leaves. This energy is then transferred to animals when they eat the plant. The animals transform chemical energy from the food they eat into energy that fuels all the processes in their bodies (Figure 7.7.2). The transfer and transformation of energy through ecosystems is essential for the survival of the entire ecosystem.

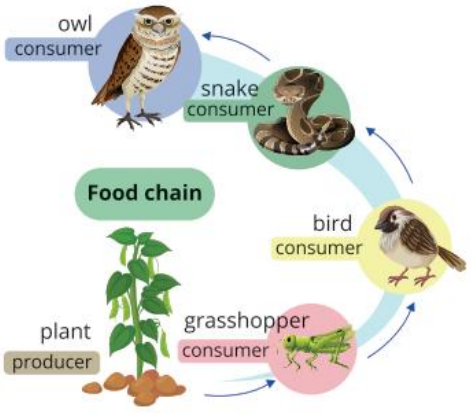


FIGURE 7.7.2 Both food chains and energy pyramids are simple energy diagrams that show the transfer of energy between organisms.

SC 1 CHECK YOUR UNDERSTANDING

Identify the energy transformations involved when a child swings back and forth on a swing.

SC 2 I can explain why not all forms of energy transfer and transformation are useful

KEY TERM

law of conservation of energy energy cannot be created or destroyed, but can only be transferred from one object to another or transformed into another form of energy

The **law of conservation of energy** says that no energy is created or destroyed. Instead, energy is transferred or transformed into different forms. During energy transformations, energy is sometimes transformed into energy that is not useful for the system.

For example, when you bounce a ball (Figure 7.7.3), some of the kinetic energy is transformed into heat and sound as the ball hits the ground. This means that it does not bounce up to the same height as it was dropped from. The energy is not lost—it is transformed to forms of energy that are not useful. Energy that is not useful for the system is sometimes referred to as wasted energy.

The efficiency of an energy transformation describes the amount of useful energy transformed. In the case of the bouncing ball, the efficiency will be high for balls that bounce back to almost the same height as they are dropped from.

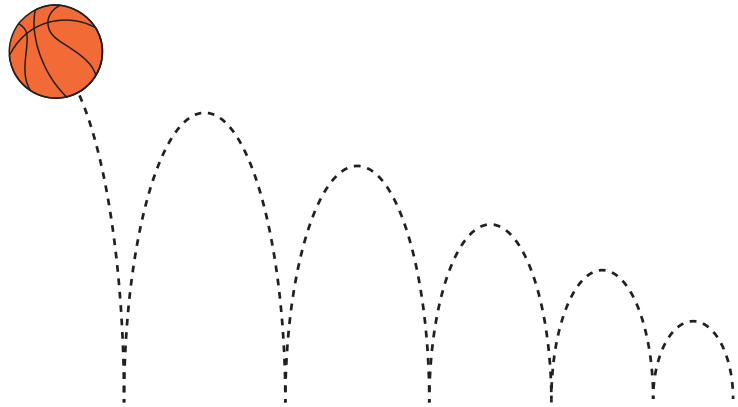


FIGURE 7.7.3 The bounce height of a ball decreases over time; as it bounces, energy is 'wasted' as sound and heat.

Table 7.7.1 details some examples of energy transformations, including the forms of waste energy produced, and the efficiency of the transformation.

TABLE 7.7.1 Energy transformation examples

Example	Transformation	Form of waste	Efficiency (%)
candle	chemical energy → electromagnetic energy (light)	heat	0.2–1.0
incandescent bulb	electrical energy → electromagnetic energy (light)	heat	2–10
LED bulb	electrical energy → electromagnetic energy (light)	heat	10–50
petrol engine	chemical energy → kinetic energy	heat; sound	15–30
diesel engine	chemical energy → kinetic energy	heat; sound	30–50
electric engine	electrical energy → kinetic energy	heat; sound	70–90

SC 2 CHECK YOUR UNDERSTANDING

Identify a form of energy that would be considered wasted in a refrigerator.

SC 3 I can draw diagrams to demonstrate the transfer and transformation of energy in a range of living and non-living systems

Energy transformations can be represented using an **energy flow diagram**. The energy flow diagram in Figure 7.7.4, for example, shows the energy transformations involved in a light bulb producing light.

Electrical energy is transformed into the useful light energy in the light bulb as well as wasted heat energy. The size of each arrow in the diagram indicates the amount of each form of energy. For instance, the heat energy produced by the light bulb is much greater than the useful light energy.

When drawing your own energy diagrams, keep in mind the following points.

- Include arrows that point in the direction of the flow of energy in the system.
- The size of the arrows indicates the relative amount of energy.
- Label the type of energy at each point in the transformation (e.g. kinetic energy or gravitational potential energy).
- Label whether the output energy is useful or wasted energy.

KEY TERM

energy flow diagram a diagram using arrows that shows the way energy is transferred or changed into other forms

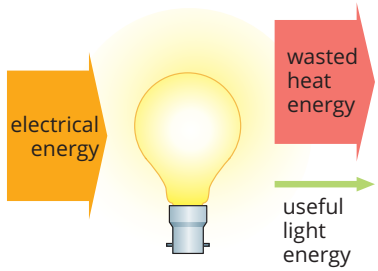


FIGURE 7.7.4 An energy flow diagram showing the transformation of electrical energy into light and wasted heat

SC 3 CHECK YOUR UNDERSTANDING

Draw a diagram to demonstrate the energy transfer and transformation in a wind turbine.

Lesson review

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

1. Identify a scenario which demonstrates each of the following energy transformations.
   - a gravitational potential energy → kinetic energy
   - b elastic potential energy → kinetic energy
   - c chemical potential energy → kinetic energy
2. Describe how a rubber band can be used to demonstrate the transformation of elastic potential energy into kinetic energy.
3. Describe a scenario where the energy transformation is not entirely useful.
4. Explain why energy 'lost' as heat during a mechanical process is often considered wasteful.
5. Draw a diagram showing energy transformation in a solar panel which transforms light into electrical energy with 20% efficiency.
6. Consider a roller coaster at the top of a hill.
   - a Describe the energy of the roller coaster while it is at the top of the hill.
   - b Describe the energy transformation that occurs as the roller coaster descends.
   - c Identify the point at which the roller coaster has maximum kinetic energy.

7.8 Investigating types of energy transformation

Learning intention

To analyse observed energy transformations

Success criteria

SC 1: I can analyse information collected from an experiment to draw conclusions.

SC 2: I can construct diagrams that describe energy changes.

Introduction

An energy transformation occurs when energy is transformed from one form to another. Some examples are a:

- car engine transforming chemical potential energy from petrol into kinetic energy that causes the car to move
- light bulb transforming electrical energy into light energy (Figure 7.8.1)
- wind turbine transforming kinetic energy into electrical energy
- toaster transforming electrical energy into heat energy to toast bread.

In this practical investigation, you will be observing a range of energy transformations and identifying the forms of energy involved.



FIGURE 7.8.1 A child reading a book by the light of a torch

Background

Many everyday situations involve energy transforming from one form to another. Often, more than one energy transformation is involved.

Aim

To observe a range of energy transformations and identify the forms of energy involved using energy flow diagrams

Materials

- matches
- torch
- tennis ball
- phone
- pop ball/rubber ball
- 50 g hanging mass
- retort stand and clamp
- 40 cm piece of string
- small wind-up toy

Assessment of risk

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

SAFETY NOTE

- Make sure no one is standing too close to the hanging mass when it is released.

Method

1. Play music on a phone for 5 seconds, then turn it off.
2. Compress a pop ball and leave it on a bench as you watch it.
3. Light a match and then carefully blow it out.
4. Turn on a torch and see what happens. Switch the torch off.
5. Suspend a hanging mass from a retort stand. Pull the mass upwards in an arc, then carefully release it and allow the mass to swing.
6. Wind up a toy and release it on a bench top.

Results

As you complete each task, record your observations in a results table in your notebook. The headings for this table should include:

Situation, Initial type of energy present, Observations, and Energy flow diagram

Conclusion

1. In which of the tested situations was the initial source of energy a type of potential energy?
2. Identify and explain which energy transformation was the most complex in terms of its energy flow diagram.
3. Which form of energy do all these transformations output?

7.9 Investigating energy transformations—chemical to electrical to kinetic

Learning intention

To be able to demonstrate how chemical potential energy can be converted to electrical energy by constructing an electrical system powered by batteries

Success criteria

SC 1: I can set up a system that converts chemical potential energy in a battery to electrical energy and then to a form of kinetic energy.

SC 2: I can describe the function of the components used in energy transformations.

SC 3: I can use diagrams to describe the process of energy transformation, including energy that is lost from the system.

Introduction

Electric circuits are made up of different components connected by wires so that electrical energy can flow. A power source is needed to supply energy to the system. Within an electric circuit, different energy transformations can occur.

In this practical investigation, you will practise setting up an electric circuit that transforms chemical potential energy into kinetic energy.

Background

Electric current in a circuit is the motion of electrons through a wire. It is the movement of the electrons that is the kinetic energy, and this is observed as electricity.

Batteries are a source of chemical potential energy. The chemical reaction inside the battery transfers energy to the electrons. This energy is in the form of kinetic energy that causes the electrons to move through the circuit. As they move, the electrons' energy is transformed into other forms, such as light, heat, mechanical energy and energy stored in magnetic fields. Discuss with your classmates different uses for batteries in your daily life. What kinds of energy transformations happen in the process?

Aim

To practise making electric circuits and to explore the energy transformations that occur

Materials

- D-cell battery in holder (maximum 6 V)
- electrical lead wires and alligator clips
- plastic cup
- sticky tape
- paperclips
- light-emitting diode (LED)
- motor
- fan blade
- resistor

SAFETY NOTES

- Avoid contact with live wires in the electrical circuit and sharp materials such as blades and nails.
- Keep the electric circuits away from any water.

Assessment of risk

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

Method

1. Build the circuit shown in Figure 7.9.1. Make sure that you use leads to connect the positive (+) side of the LED, which is the longer 'leg', to the positive terminal on the battery. Join the negative (–) side of the LED to the negative terminal of the battery.
2. Connect the alligator clips to the battery. Note that when connecting to the LED, there must be a resistor connected in series in the circuit (to protect the LED from too high an electric current). Does the LED turn on?
3. Unclip one of the alligator clips from the power source. Does the LED stay on?
4. Replace the LED with the motor and attach the fan blade.
5. Reattach the alligator clip to the power source. Does the fan start to spin?

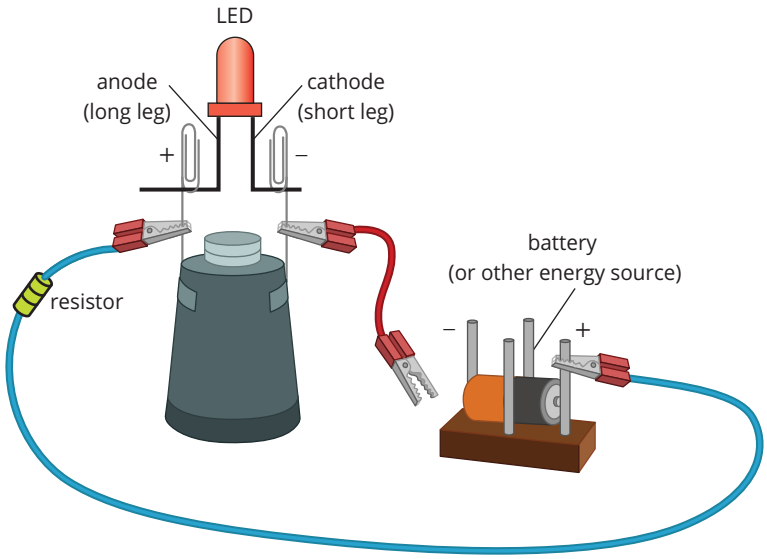


FIGURE 7.9.1 A diagram of the circuit set-up

Evaluation

1. When you connected the power source to the LED, did the LED turn on?
2. When you disconnected the alligator clip from the power source, did the LED stay on?
3. Describe the kinetic energy of the electrons in the circuit when connected to a power source.
4. Draw an energy transformation diagram of the circuit connected to the LED.
5. Draw an energy transformation diagram of the circuit connected to the motor and fan.
6. Explain how each of the following components in the circuit are involved in energy transfer or transformation.
   a. battery
   b. wires
   c. motor
   d. fan

7.10 Energy transfers and transformations used by First Nations Australians

Learning intention

To understand ways that First Nations Australians use knowledge of energy in traditional fire-starting methods

Success criteria

SC 1: I can describe, using diagrams, energy transfer and transformation in traditional fire-starting methods used by groups of First Nations Australians.

SC 2: I can compare and contrast different traditional fire-starting methods used by First Nations Australians.

SC 3: I can describe why fire is important to First Nations Australians.



FIGURE 7.10.1 Effectively controlling bushfires in Australia requires a deep understanding of its unique environment.

Lesson overview

Humans have a long and complex history with fire. Traditionally, it has provided light, warmth, food and protection. It has also caused great damage, particularly here in Australia through bushfires (Figure 7.10.1). Nevertheless, Australia's First Nations people maintain a unique and sustainable connection with fire.

In this lesson, you will learn about the different fire-starting methods used by First Nations Australians and explore the cultural significance of fire in First Nations communities.

SC 1 I can describe, using diagrams, energy transfer and transformation in traditional fire-starting methods used by groups of First Nations Australians

To light a fire, you need three essential elements, often referred to as the fire triangle: fuel, oxygen and a heat source.

Heat energy can be introduced to the fuel through various methods such as a spark, an open flame, electrical resistance, chemical reactions, or even focused sunlight (e.g. through a magnifying glass). Once the fire has started, the chemical potential energy stored in the fuel is transformed into heat and light in the presence of oxygen.

Another way to introduce heat to the fuel is friction. Before the 1800s, there were four main fire-starting methods employed by different cultures and communities around the world, all of which used friction. These were the:

- fire drill
- fire saw
- fire plough
- percussion method.

In most cultures, just one of these methods was used. In Australia, among First Nations communities, the knowledge of all four has been passed down through the generations.

In the fire drill (Figure 7.10.2), fire saw and fire plough methods, the friction generated between two pieces of wood heats kindling to produce embers. Oxygen is added to the system by blowing on the embers until a fire starts.



FIGURE 7.10.2 A traditional display of fire making by the drill method in Tjapukai Park near Cairns, Queensland

In the percussion method, two stones are hit together so that small shards of the stones break away. The friction generated between the two stones means that these broken shards are very hot. As they react with the surrounding air, sparks are produced which land on the timber (fuel) to start the fire.

In all these fire-starting methods, it is possible to describe the energy transformations that are occurring using an energy diagram like that shown in Figure 7.10.3.

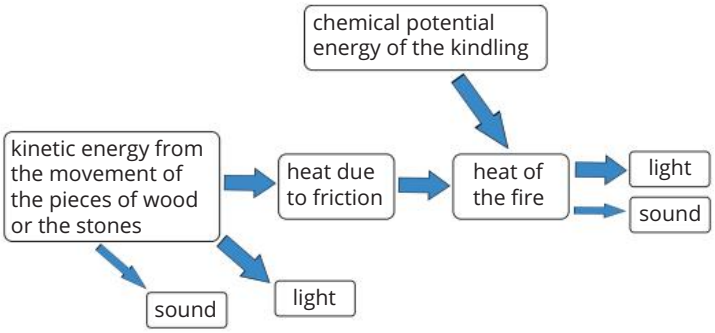


FIGURE 7.10.3 An energy flow diagram for friction fire-starting methods

SC 1 CHECK YOUR UNDERSTANDING

Create a diagram showing the energy transfer and transformation in the fire-drill method.

SC 2 I can compare and contrast different traditional fire-starting methods used by First Nations Australians

First Nations Australians' fire-starting methods

The fire drill, fire plough, fire saw and percussion methods are all traditional fire-starting techniques used by First Nations Australians. In each case, they rely on the transformation of kinetic and potential energy into heat energy to create fire. The fire drill and the fire saw techniques are the most used methods by First Nations Australians.

Fire drill

In the fire drill method (Figure 7.10.4) a straight and slender stick (drill) is inserted into a groove on a flat wooden base. The drill is rotated rapidly to create friction that generates heat. Because the base is made from a softer or less dense wood than the drill, sawdust accumulates in the groove as the drill spins, which is in turn transformed into a smouldering ember by the heat energy produced. This ember can then be used to ignite nearby kindling or to start a fire. The fire drill method is a very skilful motion that is hard to achieve and can take time to learn to do efficiently. However, because the energy is concentrated on a single point, it can start a fire more quickly than other methods.

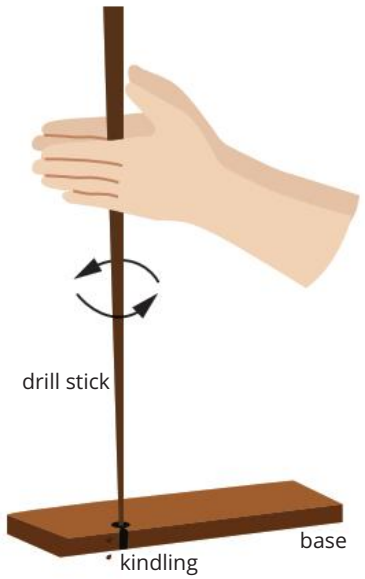


FIGURE 7.10.4 The apparatus for the fire drill method

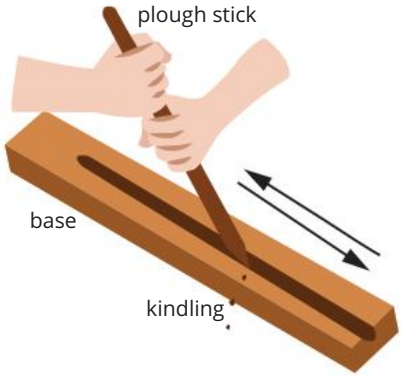


FIGURE 7.10.5 The apparatus for the fire plough method

Fire plough

In the fire plough method (Figure 7.10.5), a slender stick (plough) is set within a groove on a flat wooden base. The stick is then pushed rhythmically back and forth along the groove to create friction that generates heat. Much like the fire drill method, the plough's base is crafted from softer or less dense wood than the plough itself. As this back-and-forth motion continues, sawdust accumulates in the groove to be transformed by the heat into a smouldering ember. The ember is subsequently used to ignite the fire.

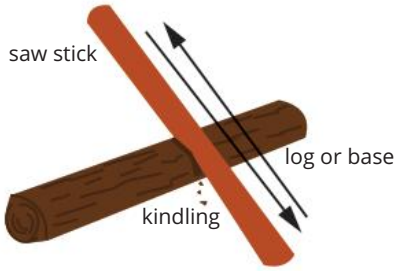


FIGURE 7.10.6 The apparatus for the fire saw method

Fire saw

In the fire saw method (Figure 7.10.6) a hard and sharp piece of wood (saw), is securely inserted into a base piece of wood, often a branch. Alternatively, tools such as a boomerang or a wooden knife can be used as the 'saw'. To generate heat, a sawing motion (moving the sharp piece of wood back and forth) is employed. This action creates an ember, which can then be used to ignite nearby kindling or tinder.



FIGURE 7.10.7 The apparatus for the percussion method

Percussion method

In the percussion method (Figure 7.10.7), two stones are struck together, causing small pieces of each to break off. The friction generated by the impact heats these small stone fragments. Upon contact with the air, the hot fragments then ignite, creating sparks that can be used to light the surrounding kindling and tinder.

SC 2 CHECK YOUR UNDERSTANDING

Explain one key difference between the fire drill and the fire saw methods.

SC 3 I can describe why fire is important to First Nations Australians

Fire plays diverse and vital roles within First Nations Australian communities. Its wide-ranging applications include cooking, ceremonial activities, storytelling, traditional medicine and land management practices.

The significance of fire in these different contexts is discussed in more detail below.



FIGURE 7.10.8 First Nations Elder Uncle Max Eulo performs the smoking ceremony at the Domain, Sydney, to commemorate the Sydney Festival.

Smoking ceremonies

Smoking ceremonies (Figure 7.10.8) hold significant cultural and spiritual importance for many First Nations Australians. These ceremonies involve the controlled and purposeful use of smoke, typically generated by pleasant-smelling substances such as native eucalyptus leaves. The smoke is believed to possess cleansing and purifying properties, and smoking ceremonies are important for spiritual, medicinal and environmental reasons.

Land management

First Nations Australians have a long history of using an important practice known as 'cool burning' (Figure 7.10.9). Cool burns are carefully controlled, low-intensity fires that serve various land and ecosystem purposes. Conducted over extended periods, cool burns play a crucial role in wildfire prevention, as well as promoting biodiversity and habitat creation.

One remarkable outcome of this practice, for example, is the adaptation of certain plant species. Over time, the DNA of plants has evolved to respond to cool burns by germinating after the fires have passed. This adaptation can be observed in species like acacias, which have developed seed pods that open in response to low heat.



FIGURE 7.10.9 A controlled burn in Kakadu, skilfully conducted to steward the land and maintain its ecological balance

Ground ovens

Cooking methods among First Nations Australians are incredibly diverse, showcasing the resourcefulness of these cultural groups. One method involves heating rocks in the fire, then transferring them to a ground oven.

Ground ovens (Figure 7.10.10) are used to prepare a variety of foods efficiently. This approach is like cooking shellfish directly on the coals of a fire without the presence of flames. It highlights the ingenuity and adaptability of First Nations Australian cooking techniques, which are deeply rooted in their connection with the land and its resources.

A ground oven is constructed by digging a pit and lining it with stones. A cover, often made of leaves or cloth, is used to retain the heat. The food, positioned on the pit's bottom or a rack, undergoes slow, controlled cooking as the cover helps maintain moisture and regulate temperature.

Scifile

Cooking food

When you cook food, heat energy is transformed into chemical energy, changing the food's texture and flavour. This transformation makes food safer and more enjoyable to eat.

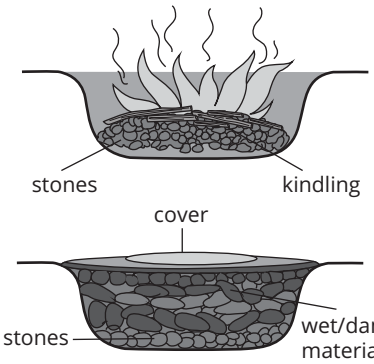


FIGURE 7.10.10 A ground oven; the stones are heated before being used to cook the food.

SC 3 CHECK YOUR UNDERSTANDING

Explain why cool burns are important for Australian ecosystems.

Lesson review

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

1. Identify three reasons why fire is important to First Nations Australians.
2. Draw a diagram showing the energy transfer and transformation in the fire saw method.
3. Describe why someone may prefer the fire plough method over the fire drill method.
4. Explain how fire is used in land management by First Nations Australians.

7.11 Solving a problem using energy

Learning intention

To be able to design, create and report on a system that solves a problem using energy transfer and transformation

Success criteria

SC 1: I can design or modify a design of a Rube Goldberg machine that involves energy transfer and transformations.

SC 2: I can describe how the system is designed to maximise efficiency of energy transfers and/or transformations.

SC 3: I can create a scientific report or presentation that explains the final design.

Introduction

A Rube Goldberg machine is designed to perform a simple task in a roundabout way. For example, when the man in Figure 7.11.1 takes a spoonful of soup, this causes a complex and unnecessary chain of events (energy transformations) intended simply to bring a napkin to his mouth.

In this inquiry activity, you will create your own Rube Goldberg machine to explore different transformations of energy.

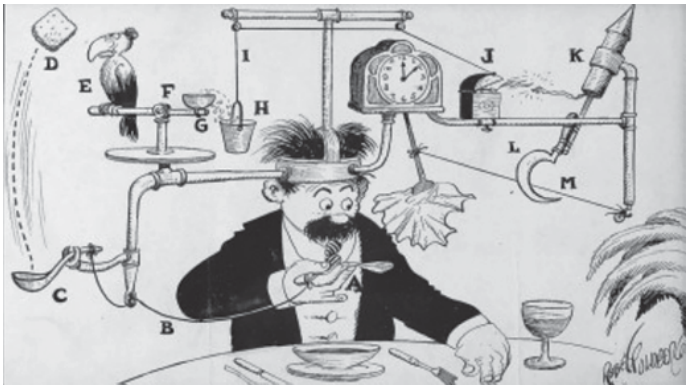
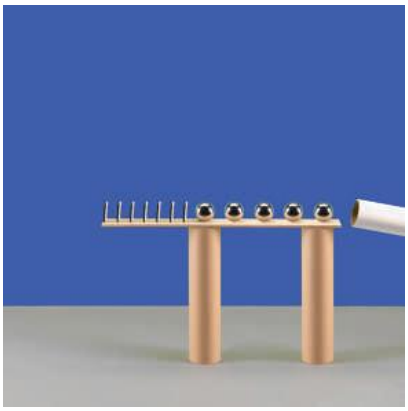
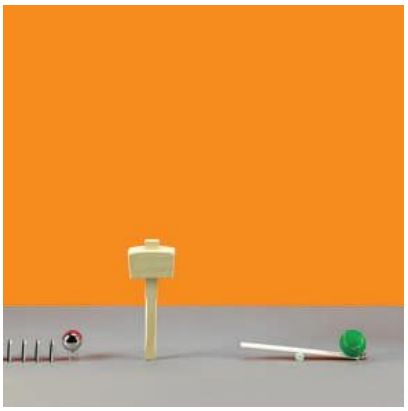


FIGURE 7.11.1 A Rube Goldberg machine often overcomplicates a simple task in a humorous manner.

Background

Rube Goldberg machines are named after a cartoonist born in 1883 who would draw cartoons of simple tasks being completed in overly complicated ways. These days, Rube Goldberg machines are usually created for entertainment. They are also an excellent way to explore how energy is transferred and transformed in a system. Some examples of energy transfers and transformations in Rube Goldberg machines are shown in Figure 7.11.2.





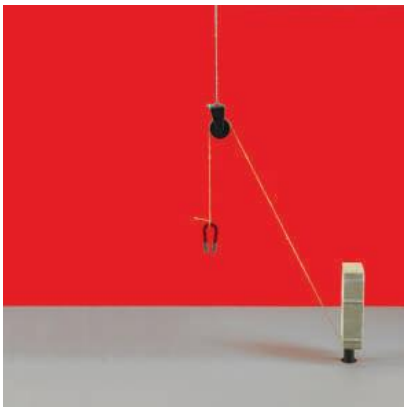


FIGURE 7.11.2 A common energy transformation used in a Rube Goldberg machine is the transformation of potential energy into kinetic energy; for example, the falling domino pushing the steel ball, the falling hammer pushing the lever, or the rope causing the balance block to fall.

Aim

To build a Rube Goldberg machine that includes at least three energy transformations

Plan

1. Determine the energy transformations that will occur in your Rube Goldberg machine. (Remember, your design needs to include at least three energy transformations.)
2. Describe the term 'efficiency' in energy transformations.
3. Explain how you will maximise efficiency for each of these transformations.
4. Decide on a materials list.
5. Decide how you will evaluate your design. Will you record your machine in action?

GO TO
Toolkit section 2.1, Reducing risk

Design

Draw a diagram of your Rube Goldberg machine. If you are struggling to think of ideas, search for Rube Goldberg machines on the internet for inspiration.

Conduct

Make notes while your Rube Goldberg machine is in action. Note anything that worked well and anything that did not work as planned. You might want to draw or paste in details of your machine as well.

HINT

Note that you will need to summarise your findings in a presentation or scientific report. Keep this in mind when planning your design.

GO TO
Toolkit section 5.1, Methods for presenting scientific ideas

Improve

1. Explain what worked and what did not work in your machine.
2. Discuss with your classmates their designs. Describe your favourite element of someone else's design.
3. Write how you can improve your machine.

Evaluate

1. Decide whether to write a scientific report or create a presentation to evaluate your design.
2. List the headings that you will use to structure your report/presentation.
3. List some of the key elements under each of your chosen headings.

7.12 Sustainable energy

Learning intention

To understand how the development of sustainable energy in vehicles has had an impact on the environment

Success criteria

SC 1: I can describe how scientific responses to contemporary issues can have a positive impact on the environment and society.

SC 2: I can describe how sustainable energy is used for vehicles.

SC 3: I can explain the environmental impacts of sustainable energy use in vehicles.



FIGURE 7.12.1 Improvements in battery technology as well as increased prevalence of charging stations have made electric vehicles more viable.

KEY TERM

renewable energy source
a source of energy that can be replaced after it is used, such as solar or wind energy

Lesson overview

As environmental concerns grow, it has become increasingly important to explore cleaner sources of energy for transportation. This can help reduce pollution and improve air quality, as well as lower the emission of gases known as greenhouse gases.

The burning of fossil fuels, such as petrol, oil and natural gas, releases large amounts of carbon dioxide (CO_2) into the air. One promising solution to this problem is the use of sustainable energy in vehicles. This includes electric, hybrid and fuel-cell vehicles, which can use renewable energy sources such as the Sun (solar), wind and water (hydro), to provide the energy required to power their engines.

In this lesson, you will learn how the development of sustainable energy in vehicles has made a positive impact on the environment.

SC 1 I can describe how scientific responses to contemporary issues can have a positive impact on the environment and society

Scientific responses to issues such as pollution can have a positive environmental impact in several ways.

Renewable energy

Scientific research can lead to the development of new technologies that may be more sustainable and environmentally friendly (Figure 7.12.1). Renewable energy technology uses a **renewable energy source** to generate power. Sources are considered renewable if they are not used up when used to generate power. For example, wind turbines (Figure 7.12.2) and solar panels have been developed to replace fossil fuels, which are used up when burnt. However, fossil fuels continue to be used to produce this equipment as well as to transport the 'renewable' energy through the grid for use.



FIGURE 7.12.2 Wind turbines transfer kinetic energy from moving air (wind) into electrical energy in a generator.

Laws and regulations

Scientific responses can provide data and information that can be used by policymakers, such as politicians and environment agencies, to develop regulations that protect the environment. For example, scientific studies on the negative impact of air pollution on human health have led to the regulation of vehicle emissions and industrial pollution.

Action on sustainability

Scientific responses can lead to the development of more sustainable practices and behaviours. For example, scientific research on the impact of plastic waste on the environment has led to an increased awareness of the need for alternative materials, recycling programs (Figure 7.12.3) and waste and water management.



FIGURE 7.12.3 Action on sustainability has led to the implementation of a container deposit scheme in all Australian states and territories, such as the one shown here at Manly Beach, New South Wales.

Sustainable energy for vehicles

Scientific responses have led to the development of **sustainable energy** use in vehicles, which forms the focus of this lesson. The use of electricity or hydrogen fuel cells in vehicles, instead of fossil fuels, can reduce greenhouse gas emissions and air pollution from the vehicle.

KEY TERM

sustainable energy a form of energy that is replenished naturally and has a minimal impact on the environment

Scientists have worked to develop more efficient and affordable batteries for electric vehicles, which has increased the range of these vehicles and improved hydrogen fuel cell technology, making it more efficient and cost-effective.

Governments have introduced regulations and incentives to encourage the use of sustainable energy sources for transportation. For example, some countries provide tax credits or subsidies for buying electric vehicles or have stated that a certain percentage of vehicles sold must be electric or use other sustainable energy sources. There has also been a shift to sustainable energy in public transport, which has helped to improve air quality and public health.

The use of sustainable energy in vehicles has been coupled with information campaigns aimed at changing behaviours towards transportation practices. As a result, some people are choosing to use electric or hybrid vehicles or are taking public transport or cycling instead of driving.



FIGURE 7.12.4 Electric trains, such as trams, are used in Australia, such as in the Sydney light rail.



FIGURE 7.12.5 Electric buses produce zero emissions, reducing air pollution in cities.

SC 1 CHECK YOUR UNDERSTANDING

Select one issue in society and describe a way the environmental impact of the issue is being reduced.

SC 2 I can describe how sustainable energy is used for vehicles

KEY TERM
greenhouse effect the warming of Earth caused by greenhouse gases

Greenhouse gases, such as carbon dioxide (CO_2), are naturally present in the atmosphere. Greenhouse gases act as heat-traps, capturing heat released from Earth's surface due to the absorption of solar energy. This phenomenon allows life to exist on Earth because without this '**greenhouse effect**', the heat would escape, and Earth would experience extremely high and low temperatures each day.

Therefore, an increase in greenhouse gases in the atmosphere may result in a rise in temperature. However, many other factors, including manufacturing processes and rainforest clearing, may also contribute to temperature rises.

Sustainable energy can be used to reduce the emission of pollution directly produced by vehicles. Here are some examples of how sustainable energy can be used to power vehicles.



FIGURE 7.12.6 A network of rapid chargers for electric vehicles in Germany

Electric vehicles

An electric vehicle uses electricity to power an electric motor that moves the vehicle. The electricity can come from renewable energy sources, such as solar or wind. Electric vehicles produce zero emissions from the exhaust pipe. This means that they do not produce pollution or greenhouse gases while they are being driven and will become increasingly popular as the network of charging stations around Australia grows (Figure 7.12.6).



FIGURE 7.12.7 Some hybrid cars can also be recharged at plug-in charging stations.

Hybrid vehicles

Hybrid vehicles use a traditional petrol engine alongside an electric motor (Figure 7.12.7). The electric motor is powered by a battery that is recharged using energy from the engine, or from the energy that is normally transformed into heat when braking. Hybrid vehicles produce fewer emissions than traditional petrol vehicles, and some models can run on electricity alone for short distances.



FIGURE 7.12.8 Hydrogen fuel cell vehicles can be refuelled at hydrogen refuelling stations.

Fuel cell vehicles

Fuel cell vehicles use hydrogen to generate electricity that powers an electric motor (Figure 7.12.8). When hydrogen is combined with oxygen in the fuel cell, it produces electricity and water vapour is its only emission. Hydrogen is most commonly produced using fossil fuels such as natural gas; however, if it can be produced from renewable energy sources, such as solar or wind power, it would make fuel cell vehicles a sustainable option.

These new technologies can help reduce the impact of transportation on the environment. However, the balance of this must be carefully considered, including the environmental costs of production and disposal of vehicles, their fuel sources, and their components. As the shift to a more sustainable future continues, an increasing number of vehicles will probably be powered by sustainable energy.

SCIENCE IN SOCIETY

Electric vehicles—not as new as you think!

Electric vehicles may appear to be new technology, only becoming commonplace in the 2020s, but the first electric vehicles were invented 200 years ago, in the 1820s and 1830s. These were little more than electric carts, which used non-rechargeable batteries to travel very short distances. Exciting, but not very practical.

The first commercially available electric car was built by the English inventor and electrical engineer Thomas Parker at the end of the nineteenth century. Parker repurposed a factory that built electric trams to develop his car (Figure 7.12.9).

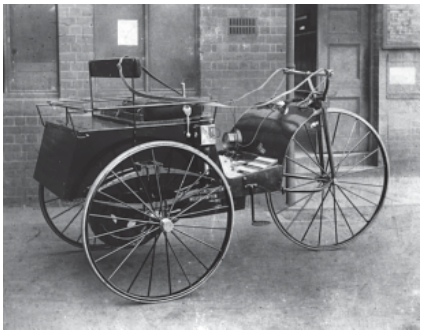


FIGURE 7.12.9 Thomas Parker's electric vehicle was a three-wheeled cart.

Electric vehicles were more common and cheaper than petrol cars at the time. They were popular because they did not suffer from the vibrations, smell and noise caused by petrol engines.

As technology improved, the disadvantages associated with petrol engines decreased, and the availability of cheap petrol increased. One of the biggest disadvantages of the petrol engine was the need to start the engine by hand. This was done by rapidly spinning a crank to cause the engine to turn-over and start (Figure 7.12.10). This was a difficult and sometimes dangerous task. You may be familiar with this method of starting an engine, as it is still used on pull-start lawnmowers.



FIGURE 7.12.10 Replacing the manual crank with an electric starter motor made petrol vehicles more popular.

Ironically, it was the electric motor that caused electric vehicles to dwindle in popularity. Electric 'starter motors' were installed in petrol cars to remove the need for hand cranking, solidifying the petrol car's position as the cheaper and more practical type of car.

SC 2 CHECK YOUR UNDERSTANDING

Describe one way that electric vehicles use sustainable energy.

SC 3 I can explain the environmental impacts of sustainable energy use in vehicles

Sustainable energy use in vehicles has both positive and negative impacts, which are important to be aware of when making decisions and choices about protecting the planet. Table 7.12.1 covers some of the positives and negatives of this technology. It is worth noting that not all entries in this list apply to all types of sustainable vehicles.

TABLE 7.12.1 An analysis of the positives and negatives for a variety of sustainable vehicles

Positives	Negatives
Lower operating costs Require less maintenance, have fewer moving parts, and use cheaper electricity than petrol or diesel vehicles.	**Initial high purchase cost** Initial purchase cost can be higher than conventional vehicles, which may pose a barrier for some buyers.
Reduced operating dependence on fossil fuels Reliance on alternative energy sources such as electricity or hydrogen means less impact of fuel price fluctuations.	**Battery disposal challenges including toxic waste products** Disposing of batteries from sustainable vehicles can pose challenges due to the presence of toxic waste materials, which need to be managed properly to minimise environmental harm.
Improved air quality from reduced emissions Producing fewer harmful emissions, such as nitrogen oxides and particulate matter, leading to cleaner and healthier local environments for communities.	**Lithium-ion battery fires are difficult to extinguish** Although rare in vehicles, lithium-ion battery fires are difficult to extinguish. This is why electric and hybrid vehicles in Australia are required to display a blue triangle on the number plate, so that emergency responders can quickly identify the need to use different procedures.
Potential to recharge battery at home Convenience of recharging battery at home, eliminating the need for frequent trips to petrol stations, and ability to draw upon solar energy at home during the day.	**Availability of charging infrastructure** Vehicles require charging infrastructure to operate. This is rapidly improving across Australia, including regional areas, but areas remain that are not well supported.
Energy efficiency Use less energy to cover the same distance as traditional vehicles.	**Charging time** Charging takes longer than refuelling—even the best chargers can take 30 minutes to recharge a car. This is not always a disadvantage because the car can be plugged in while parked, but may need to be considered for longer journeys.

SC 3 CHECK YOUR UNDERSTANDING

Identify the differences in the environmental impact of electric vehicles and traditional petrol-powered vehicles.

Lesson review

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

1. Describe how hydrogen fuel cells work.
2. Describe how renewable energy sources can address climate change.
3. Analyse the long-term environmental benefit of transitioning from fossil fuel-powered vehicles to sustainable energy vehicles, including the potential challenges in this transition.
4. Propose a change the government could make to reduce one of the negatives associated with electric vehicles.

7 Energy types in systems

Topic summary

The key concepts included in this topic are:

- There are many forms of energy, including kinetic, potential, chemical, nuclear and more.
- Energy can be transferred from one object to another.
- There are several types of kinetic energy, such as sound, heat and electrical energy.
- Collaboration between Swami Vivekananda and Nikola Tesla led to an exploration of the relationship between mass and energy.
- Efficiency describes the amount of useful energy output compared to the amount of energy wasted in a system.
- Energy transfers and transformations can be analysed in terms of efficiency.
- Heat energy can be transferred by conduction, convection, and radiation.
- Energy transfers and transformations are required for the success or sustainability of a system.
- Batteries transform chemical potential energy to electrical energy.
- First Nations Australians use knowledge of energy in traditional fire-starting methods.
- Sustainable energy use in vehicles can positively impact the environment.

Review questions

The following questions will assess your success in achieving the learning intentions for this topic.

Remember

1 List the different ways heat energy is transferred via particles.

2 Energy transfers and categories of kinetic energy are fundamental concepts in physics.

- a Define kinetic energy.
- b Identify three types of energy that involve kinetic energy due to the motion of particles.
- c Give an example of kinetic energy transfer in everyday life.

3 Provide an example of how the following types of energy can be transformed into kinetic energy.

- a chemical energy
- b gravitational potential energy
- c elastic potential energy

4 What connection did Swami Vivekananda and Nikola Tesla explore together?

Understand

5 Explain why energy transfers can never be 100% efficient.

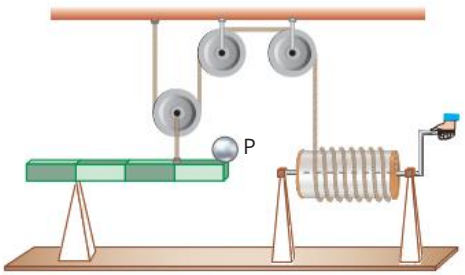
6 Explain the energy transformations involved in a traditional fire-starting method.

7 Use the particle model to describe the changes that occur when a substance is heated.

Apply

8 Draw a diagram of a simple electrical circuit that is powered by a battery.

9 Shown below is a simple Rube Goldberg machine, which causes the ball at point P to roll down the ramp. Describe each step of the machine, including any energy transfers or transformations which take place.



10 Design a simple experiment to measure the efficiency of a pendulum.

Analyse

11 Compare the transformation of energy within a heat lamp and a light bulb.

12 Compare the environmental impacts of electric vehicles and traditional petrol-powered vehicles.

13 Is it possible for an energy flow diagram to have more heat energy output than electrical energy input? Explain your answer.

Extension: Research task

14 Research how kinetic energy in the form of sound is utilised in medical technologies. Describe your findings.

Topic reflection

The learning intentions for this topic are given in each lesson and at the beginning of the topic. Consider how well you have achieved them. Note down any particular areas that you are confident in, and others where you are not so sure.

7 Glossary

chemical potential energy energy stored in molecules

conduction a method of heat transfer in which heat is travels through a material or between two objects in contact with each other

conductivity a measure of the ability of a material to conduct heat, sound or electrical energy

conductor a material through which heat, sound or electrical energy can be transferred

convection the transfer of heat through the movement of a liquid or gas

efficiency a measure of the useful energy output of an energy transfer

elastic potential energy energy stored within a stretched or compressed object, such as a spring or elastic material

electric current the flow of charged particles (electrons) through a conductor

electron a negatively charged subatomic particle, located around the nucleus of an atom

energy flow diagram a diagram using arrows that shows the way energy is transferred or changed into other forms

energy transformation the conversion of energy from one form to another, such as the conversion of potential energy into kinetic energy as an object falls

gravitational potential energy energy stored by an object due to its position above the ground

greenhouse effect the warming of Earth caused by greenhouse gases

heat a form of energy that moves from a warmer object or substance to a cooler object or substance

insulator a material that does not readily allow the transfer of heat, sound or electricity—the opposite of a conductor

kinetic energy energy possessed by a moving object

law of conservation of energy energy cannot be created or destroyed, but can only be transferred from one object to another or transformed into another form of energy

Newton's cradle a device that demonstrates the transfer of kinetic energy through a series of swinging spheres

nuclear potential energy energy stored in atoms, such as in the uranium used in nuclear power plants

particle model a model used to help describe and explain the behaviour of particles in solids, liquids and gases

potential energy energy stored by an object (because of its position or chemical structure) that can be transformed into another form of energy

radiation the transfer of heat in the form of electromagnetic waves, which can travel through a vacuum

renewable energy source a source of energy that can be replaced after it is used, such as solar or wind energy

sound a form of energy that travels as vibrating waves and can be heard by the ears as sound

sustainable energy a form of energy that is replenished naturally and has a minimal impact on the environment

system a collection of interacting components that form an integrated whole

temperature a measure of the average kinetic energy of particles in a substance that indicates how hot or cold the substance is

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