

Good Science 8

Second Edition



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Note about language

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Learning Ladder for Victoria Year 8

Steps in progression Vic V2.0 Codes →	5	I can analyse how the structure and function of cells contribute to the survival of organisms	I can analyse the relationship between structure and function at organ system levels	I can analyse the use of elements and compounds based on their properties	I can analyse models that represent physical and chemical change	I can evaluate evidence that supports the theory of plate tectonics	I can evaluate the use and extraction of rocks	I can evaluate household energy usage and propose ways to decrease energy consumption and waste	I can analyse a variety of electrical circuits and their components, designed for diverse purposes
	4	I can compare cells in plants and animals, and unicellular and multicellular organisms	I can discuss the effects of disorders in the cells, tissues or organs of systems	I can explain how different elements and compounds are used	I can compare physical and chemical changes with reference to the properties of substances	I can discuss geological phenomena, including volcanoes and earthquakes, in terms of tectonic activity	I can discuss how the properties of rocks influence their use	I can analyse energy changes in terms of energy efficiency and household consumption	I can observe and make predictions about voltage, current and energy transfer in circuits
	3	I can explain the role of specialised cell structures and organelles in cellular function	I can explain how organ systems work together to enable survival	I can represent substances using models, symbols and chemical formulas	I can explain physical and chemical changes with reference to the rearrangement of atoms	I can explain how geological features are formed by tectonic activity	I can explain how the properties of rocks relate to their formation	I can represent energy transfers and transformations in simple systems	I can design and construct series and parallel circuits
	2	I can describe the features of plant and animal cells	I can describe how cell-based structures work together to carry out specialised functions	I can distinguish between elements, compounds and mixtures	I can distinguish between physical and chemical changes based on observations	I can distinguish between different types of tectonic activity	I can differentiate between types of rock based on their properties	I can differentiate between energy transfer and energy transformation	I can describe how circuits operate, with reference to voltage and current
	1	I can identify features of cells	I can distinguish between cells, tissues, organs and organ systems	I can identify that all matter is made of atoms of elements	I can make observations during a chemical or physical change	I can identify geological features	I can identify the key processes of the rock cycle	I can identify and classify different forms of energy	I can recognise that a circuit demonstrates energy transfer
		Biological science: Cells	Biological science: Systems of living things	Chemical science: Organising matter	Chemical science: Chemical change	Earth and space science: Plate tectonics	Earth and space science: The rock cycle	Physical science: Energy	Physical science: Electricity
		VC2S8U02	VC2S8U03	VC2S8U07	VC2S8U08	VC2S8U10	VC2S8U11	VC2S8U15 VC2S8U16	VC2S8U17
Science understanding									



I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations	I can evaluate investigation questions and predictions for scientific validity	I can design and conduct reproducible investigations that consider safety, ethical and procedural factors	I can analyse processed data for patterns, trends, relationships and anomalies	I can evaluate conclusions and claims with reference to conflicting evidence and unanswered questions	I can communicate scientific findings and arguments for specific purposes to specific audiences	5
I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues	I can develop a hypothesis that predicts the relationship between investigation variables	I can generate and record data with precision, using digital tools as appropriate	I can identify and discuss trends and/or patterns in a range of dataset representations	I can create evidence-based arguments to justify conclusions or evaluate claims	I can use digital technologies to organise and communicate data and information	4
I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances	I can construct questions and predictions to investigate scientific problems	I can distinguish between variables to be changed, measured and controlled in an investigation	I can process data by using mathematical relationships and/or constructing graphs	I can use science-based explanations to support investigation findings	I can prepare a variety of representations to communicate ideas and findings	3
I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society	I can make simple predictions based on what I know and observe	I can describe ways to minimise risks for a range of investigations	I can organise and display data using tables, keys and/or models	I can describe different types of errors in an investigation method	I can select appropriate formats to communicate ideas and findings	2
I can recognise scientific problems and solutions	I can identify socio-scientific issues	I can recognise questions that can be investigated scientifically	I can identify and select appropriate equipment for scientific investigations	I can identify data from tables and graphs	I can identify errors and assumptions in an investigation	I can identify scientific terminology used to communicate information	1
Nature and development of science	Use and influence of science	Questioning and predicting	Planning and conducting	Processing, modelling and analysing	Evaluating	Communicating	
VC2S8H01 VC2S8H02	VC2S8H03 VC2S8H04	VC2S8I01	VC2S8I02 VC2S8I03	VC2S8I04 VC2S8I05	VC2S8I06 VC2S8I07	VC2S8I08	

Science as a human endeavour

Science inquiry

Steps in progression

Year 8 curriculum correlation grid

CHAPTERS 	1.0 Cells	2.0 Systems of living things
Science understanding		
Cells VC2S8U02 cell theory describes cells as the basic units of life; organisms may be unicellular or multicellular and have specialised structures and organelles (including cell walls, cell membranes, cytoplasm, nuclei containing DNA, mitochondria, ribosomes, chloroplasts and vacuoles) that perform specific functions	✓	
Systems of living things VC2S8U03 the structure of cells, tissues and organs in a plant and an animal organ system are related to their function; plant and animal organ systems enable survival of the organism		✓
Organising matter VC2S8U07 the atomic theory of matter can be used to model and explain the difference between elements, compounds and mixtures; elements, compounds and mixtures can be represented as two-dimensional and three-dimensional models, elements can be represented by symbols, and molecules and compounds can be represented by chemical formulas		
Chemical change VC2S8U08 physical changes can be distinguished from chemical changes; a chemical change can be identified by a colour change, a temperature change, the production of a gas (including laboratory preparation and testing of oxygen, carbon dioxide and hydrogen gases) or the formation of a precipitate		
Plate tectonics VC2S8U10 Earth is a dynamic planet as demonstrated by tectonic activity, including the formation of geological features at divergent, convergent and transform plate boundaries; the theory of plate tectonics is supported by scientific evidence		
The rock cycle VC2S8U11 key processes of the rock cycle occur over different timescales; the properties of sedimentary, igneous and metamorphic rocks not only reflect their formation but also impact their usefulness and determine the methods used when mined		
Energy VC2S8U15 energy exists in different forms, including thermal, chemical, gravitational and elastic, and may be classified as kinetic or potential; energy transfers (conduction, convection and radiation) and transformations occur in simple systems and can be analysed in terms of energy efficiency VC2S8U16 household energy consumption can be analysed using an energy audit and is affected by appliance choice, building design, season and climate		
Electricity VC2S8U17 electrical circuits transfer energy when current flows and can be designed for diverse purposes using different components; the operation of circuits can be explained using the concepts of voltage and current		

3.0 Organising matter	4.0 Chemical change	5.0 Plate tectonics	6.0 The rock cycle	7.0 Energy	8.0 Electricity
✓					
	✓				
		✓			
			✓		
				✓ ✓	
					✓

CHAPTERS 	1.0 Cells	2.0 Systems of living things
Science as a human endeavour		
Nature and development of science VC2S8H01 scientific knowledge, including models and theories, can change because of new evidence VC2S8H02 multidisciplinary endeavours to advance scientific knowledge make use of people's different perspectives and worldviews	✓ ✓	✓ ✓
Use and influence of science VC2S8H03 proposed scientific responses to socio-scientific issues impact on society and may involve ethical, environmental, social and economic considerations VC2S8H04 communication of scientific knowledge has a role in informing individual viewpoints, and community policies and regulations	✓ ✓	✓ ✓
Science inquiry		
Questioning and predicting VC2S8I01 investigable questions, reasoned predictions and hypotheses can be developed in guiding investigations to identify patterns, test relationships and analyse and evaluate scientific models	✓	✓
Planning and conducting VC2S8I02 reproducible investigations to answer questions and test hypotheses can be planned and conducted, including identifying independent, dependent and controlled variables where applicable, stating assumptions, recognising and managing risks, considering ethical issues and following protocols when accessing cultural sites and artefacts on Country and Place VC2S8I03 equipment can be selected and used to generate and record data with attention to precision, using digital tools as appropriate	✓ ✓	
Processing, modelling and analysing VC2S8I04 data and information can be organised and processed by selecting and constructing representations including tables, graphs, keys, models and mathematical relationships VC2S8I05 information and processed data can be analysed to show patterns, trends and relationships, and to identify anomalies		
Evaluating VC2S8I06 scientific methods, conclusions and claims can be analysed to identify assumptions, possible sources of error, conflicting evidence and unanswered questions VC2S8I07 evidence-based arguments can be constructed to support conclusions or evaluate claims, including consideration of ethical issues and protocols associated with using or citing secondary data or information		
Communicating VC2S8I08 communicating ideas, findings and arguments for specific purposes and audiences involves the selection and use of appropriate presentation formats, scientific vocabulary, models and other representations, and may include the use of digital tools		✓

3.0 Organising matter	4.0 Chemical change	5.0 Plate tectonics	6.0 The rock cycle	7.0 Energy	8.0 Electricity
✓	✓	✓	✓	✓	✓
✓	✓	✓	✓	✓	✓
✓	✓	✓	✓	✓	✓
✓	✓	✓	✓	✓	✓

					✓
✓	✓	✓			
✓	✓	✓			
✓			✓	✓	
✓			✓	✓	
	✓	✓			✓
	✓	✓			✓
			✓	✓	

1.0 Cells

All living things are made up of cells. From the minuscule bacteria that we need a microscope to see, right up to the massive whales that live in the ocean, every living thing starts as a single cell. Cells are the fundamental unit of life. All of the plants and animals you see in your daily life contain similar types of cells that work together to perform all the functions they need to carry out in order to survive. These cells contain special components that allow them to complete these functions. Humans are made up of 30–40 trillion cells!



Figure 1.1: Bacteria cells like this one are so small, we need microscopes to see them.

Learning Ladder

The Learning Ladder for each chapter maps the Science Understanding, Science as a Human Endeavour and Science Inquiry strands that will be covered. Each ladder has five levels of progression, called steps. To climb the ladders, you need to develop fluency at each step. This will help you develop the ability to complete tasks that are more complex.

Steps in progression	5	I can analyse how the structure and function of cells contribute to the survival of organisms	I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations
	4	I can compare cells in plants and animals, and unicellular and multicellular organisms	I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues
	3	I can explain the role of specialised cell structures and organelles in cellular function	I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances
	2	I can describe the features of plant and animal cells	I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society
	1	I can identify features of cells	I can recognise scientific problems and solutions	I can identify socio-scientific issues
		Biological science: Cells	Nature and development of science	Use and influence of science
		Science understanding	Science as a human endeavour	



Figure 1.2: All living things, even this humpback whale, start their life as a single cell.

<p>I can evaluate investigation questions and predictions for scientific validity</p>	<p>I can design and conduct reproducible investigations that consider safety, ethical and procedural factors</p>	<p>5</p>
<p>I can develop a hypothesis that predicts the relationship between investigation variables</p>	<p>I can generate and record data with precision, using digital tools as appropriate</p>	<p>4</p>
<p>I can construct questions and predictions to investigate scientific problems</p>	<p>I can distinguish between variables to be changed, measured and controlled in an investigation</p>	<p>3</p>
<p>I can make simple predictions based on what I know and observe</p>	<p>I can describe ways to minimise risks for a range of investigations</p>	<p>2</p>
<p>I can recognise questions that can be investigated scientifically</p>	<p>I can identify and select appropriate equipment for scientific investigations</p>	<p>1</p>
<p>Questioning and predicting</p>	<p>Planning and conducting</p>	<p>Steps in progression</p>
<p>Science inquiry</p>		

1.1 ▶ What are cells?

Learning intention

At the end of this lesson, I will be able to explain what a cell is and outline the components of cell theory.

Key terms

cell: the smallest functional unit of an organism

hypothesis: a suggested explanation or prediction of a scientific problem that can be tested with an investigation

scientific theory: an explanation of a natural phenomenon that is supported by evidence and the results of repeated tests

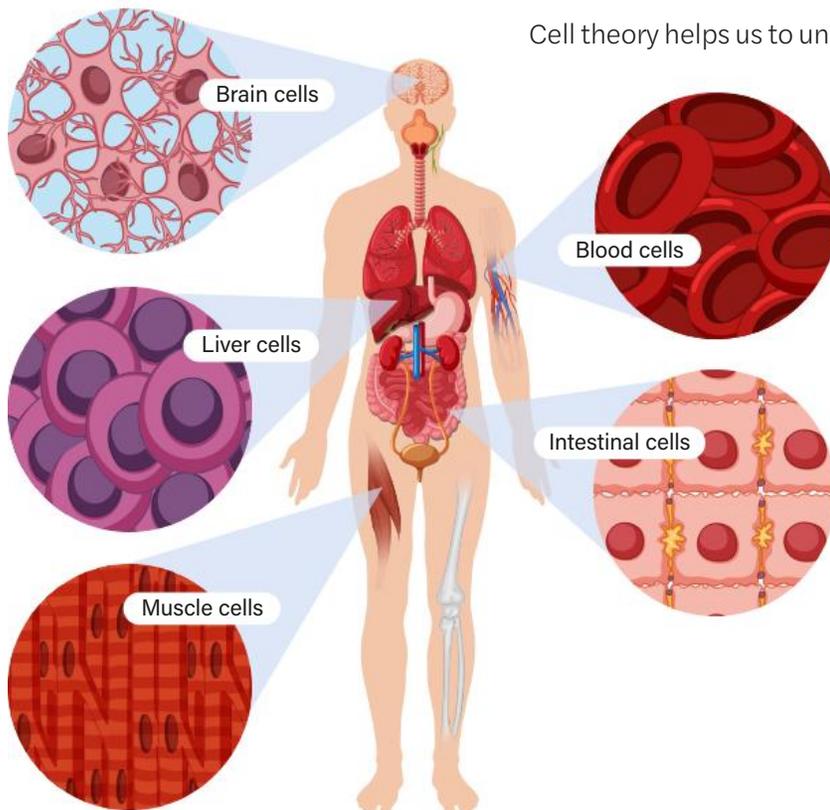
Investigation 1.1

Examining cells under a microscope, p. 295

Key idea: Form and function

Figure 1.3: The human body contains many types of specialised cells, which all have different roles.

Cells of the human body



Cells are the smallest structural and functional units of living things. This means that a cell is the smallest part of a living thing that can carry out the functions needed for life, on its own.

All living things are made of one or more cells, which come from other cells

Cells were first identified in 1665 by English scientist Robert Hooke. He was using a simple microscope to study the bark of a cork tree. The tiny structures he could see through the microscope reminded him of the tiny rooms that monks sleep in, which are called cells. From then on, many scientists used microscopes to view cells, which were now visible to them.

Even after cells had been discovered, scientists were not sure whether all organisms were made of them. Then, in 1839, the physician and physiologist Theodor Schwann developed a **hypothesis** about cells. All the evidence and discoveries made since then have confirmed this 19th-century idea, which is now recognised as a **scientific theory** called cell theory.

There are three parts to the theory of cells:

- All living things are made of one or more cells.
- Cells are the basic building blocks of life.
- Cells come from cells that already exist.

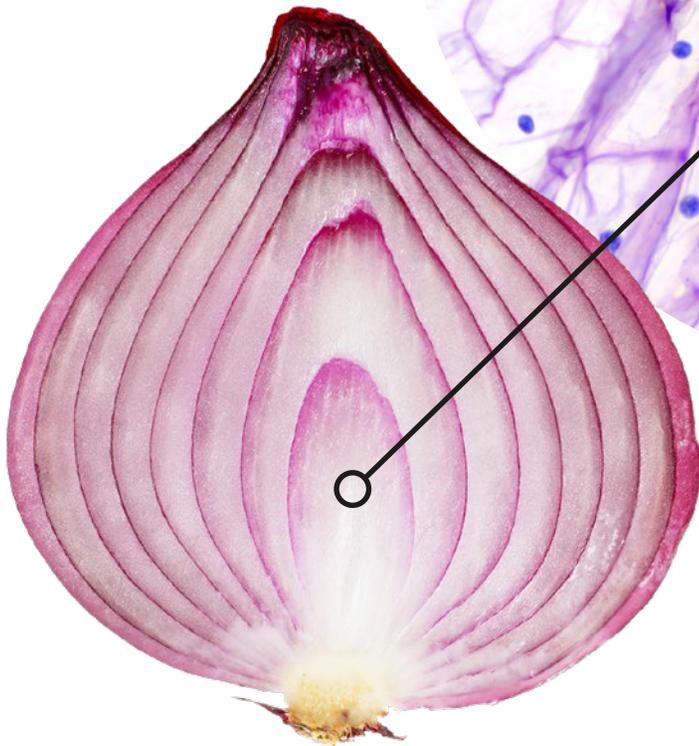
Cell theory helps us to understand how cells are relevant to all living things.

Cells are the building blocks of life

Cells are the basic building blocks of all living things. Sometimes a single cell is a complete – but very simple – organism (e.g. a bacterium). More complex organisms (such as humans) are made up of many cells that work together to perform different functions (see Figure 1.3).

The human body is made up of trillions of cells. They provide structure, take in nutrients from food, change those nutrients into energy and carry out other functions. Our cells contain our genetic material and can make copies of themselves. This allows us to grow new cells, such as for hair and fingernails.

Figure 1.4: An onion is made ▶ of many cells. The cells in a thin layer of onion membrane can be seen under a light microscope.



Microscopes allow us to see and identify cells

Cell size can vary a lot. The largest cells are ostrich eggs: a single unfertilised egg cell is about 15 centimetres wide and weighs more than one kilogram! Red blood cells are only 0.008 millimetres wide; a line of 125 red blood cells is only 1 millimetre long. Most cells are about this size, which is far too small for us to see with the naked eye.

Scientists use microscopes to see cells. The word comes from two ancient Greek terms: *micro*, which means 'small', and *scope*, which means 'to see'. A microscope is a tool for looking at small things.

The most common type of microscope in science laboratories is a light microscope. It allows scientists to study cells by shining a bright light through an extremely thin slice of tissue (usually 0.01 millimetres thick) from an organism (see Figure 1.4).

Learning Ladder

Cells

- 1 Identify the three features of cell theory.
- 2 Describe some of the differences you can see between the different human body cells in Figure 1.3.
- 3 Explain why cells are the 'building blocks of life'.

Nature and development of science

- 1 Identify a problem that microscopes helped solve.
- 2 Propose how the work of prior scientists helped Schwann to form his hypothesis about cells.
- 3 Explain how the microscope provided us with new evidence about the structure of living things.
- 4 Discuss how the development of microscopes aligns with our understanding of cells.
- 5 Research and analyse the similarities and differences between Robert Hooke's and Theodor Schwann's scientific perspectives.

Questioning and predicting

p. 232

- 1 Using Figure 1.4, propose two questions about the size of cells of different organisms that could be explored using a microscope. Identify whether your questions can be investigated scientifically.
- 2 Make a prediction about what you would find out for each question from Question 1.

Key idea: Form and function

Consider Figure 1.4. Describe how the cells you can see in the microscope image allow the onion to be formed.

Success criteria

- I can explain what a cell is.
- I can outline the components of cell theory.

1.2 ▶ Cell structures

Learning intention

At the end of this lesson, I will be able to:

- describe the common parts of plant and animal cells
- identify the similarities and differences in the structures (organelles) of plant, animal, fungi and bacteria cells.

Key terms

adenosine triphosphate (ATP):

the chemical energy made in cell organelles that living things use to carry out functions

cell membrane: a thin layer around a cell that controls which substances enter and leave the cell

cell wall: a stiff layer around a plant cell that supports it

chloroplast: a small organelle in a plant cell that makes food for the plant

cytoplasm: a jelly-like fluid inside a cell

DNA: the genetic information inside a body's cells

eukaryote: an organism with a nucleus and complex structures inside its cell(s)

mitochondria: a complex, oval-shaped organelle that produces ATP energy through the process of respiration

nucleus: the control centre of a cell; contains DNA

organelle: a structure within a cell

prokaryote: a simple organism that does not have a nucleus

ribosome: a small, simple organelle that produces proteins

vacuole: an organelle used for the storage of waste (animals) and water (plants)

Investigation 1.2

Examining cell structures, p. 297

Key idea: Form and function

Cells are made up of different parts, and different cells have different roles.

Cells have different parts called organelles

Each cell has many different parts. Each part has a particular job that helps to keep the cell healthy. However, not every cell has the same parts. For example, a plant cell has more parts than an animal cell. Scientists call the parts of a cell **organelles**.

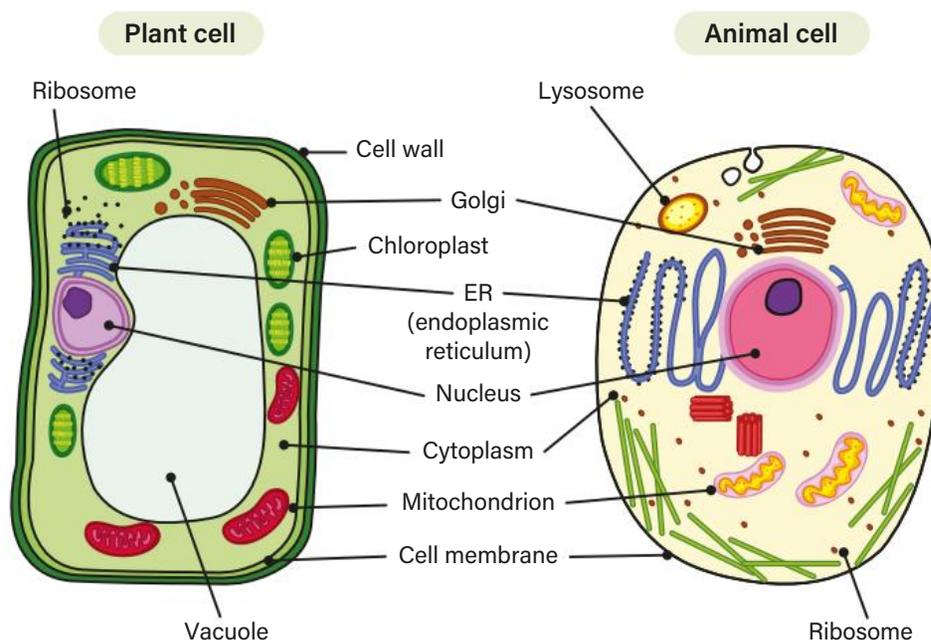


Figure 1.5: Plant and animal cells have some features in common.

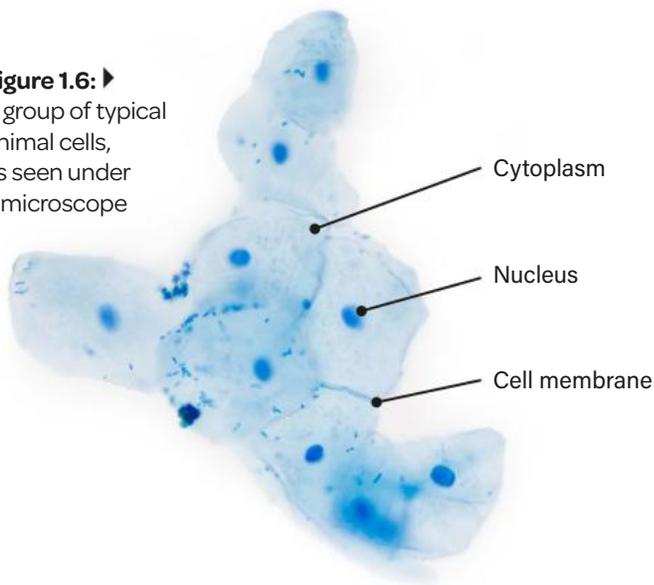
Animal, plant and fungi cells have a nucleus, mitochondria and vacuoles

The cells of all animals, plants and fungi (e.g. mushrooms and moulds) have three organelles in common:

- **Nucleus:** This is the central part of a cell. It controls all the cell's activity. **DNA**, the genetic material, is located inside the nucleus.
- **Mitochondria:** These oval-shaped organelles are unique to complex organisms that contain a nucleus. They use glucose and oxygen to produce **adenosine triphosphate (ATP)** energy in the process of respiration. (There is more on this in Section 1.4.)
- **Vacuoles:** In animals and fungi, some cells have small vacuoles to store waste products. In plants, most cells have large vacuoles that store water to help maintain the shape of the cell.

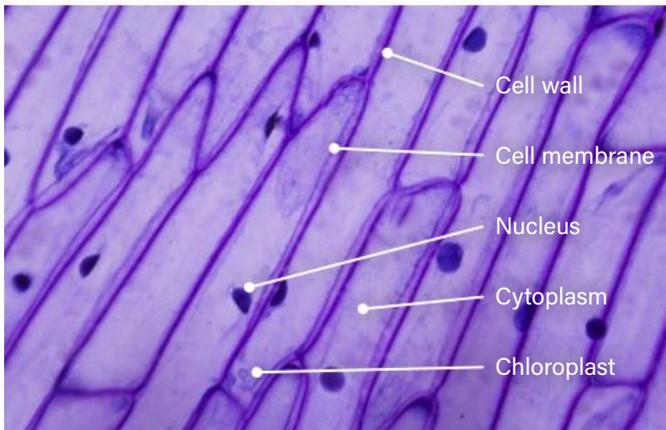
Figure 1.5 shows the features plant and animal cells have in common.

Figure 1.6: ▶
A group of typical animal cells, as seen under a microscope



- **Cell membrane:** This is a flexible, thin layer around a cell (like an envelope surrounding a birthday card). It controls substances coming in and out of a cell.
- **Cytoplasm:** This is a jelly-like fluid in which cell organelles sit. Many of the chemical reactions in a cell happen in the cytoplasm.
- **Ribosomes:** These small organelles are where proteins are produced in the cell. Without proteins, cells could not function, making this organelle essential to all living things!

Figure 1.7: A group of typical plant cells, as seen under a microscope



Plant cells have a cell wall and chloroplasts

There are many obvious differences between plants and animals. No one is likely to confuse a cat with a cactus, or a shark with seaweed!

However, some differences are not obvious, such as the organelles inside plant and animal cells. Like animal cells, plant cells have a nucleus, cytoplasm and cell membrane. However, they also have two structures that animal cells do not:

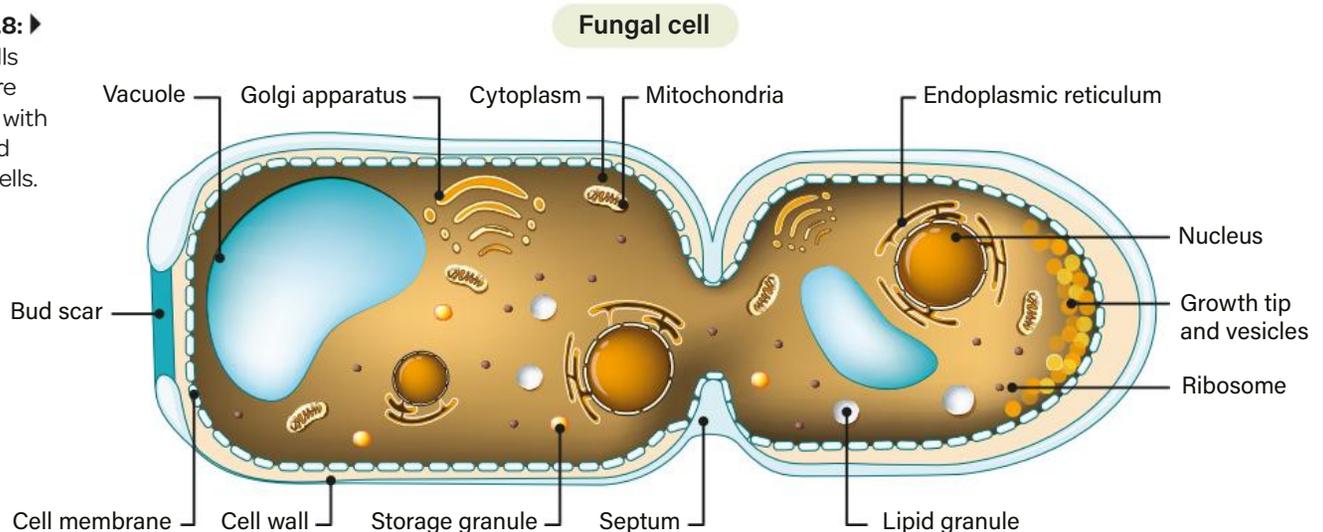
- A **cell wall:** This is a stiff layer around a plant cell, outside the cell membrane. It helps to protect and support the cell.
- One or more **chloroplasts:** Chloroplasts are organelles that act as energy producers. They are where plants make sugar using the Sun's energy.

Animal cells do not have these organelles because they do not need them. Animals have a skeleton to provide support and they can move around to get food.

All cells contain simple organelles

All cells need to use the genetic information in their DNA to produce proteins. This means that all cells have a cell membrane, cytoplasm and ribosomes.

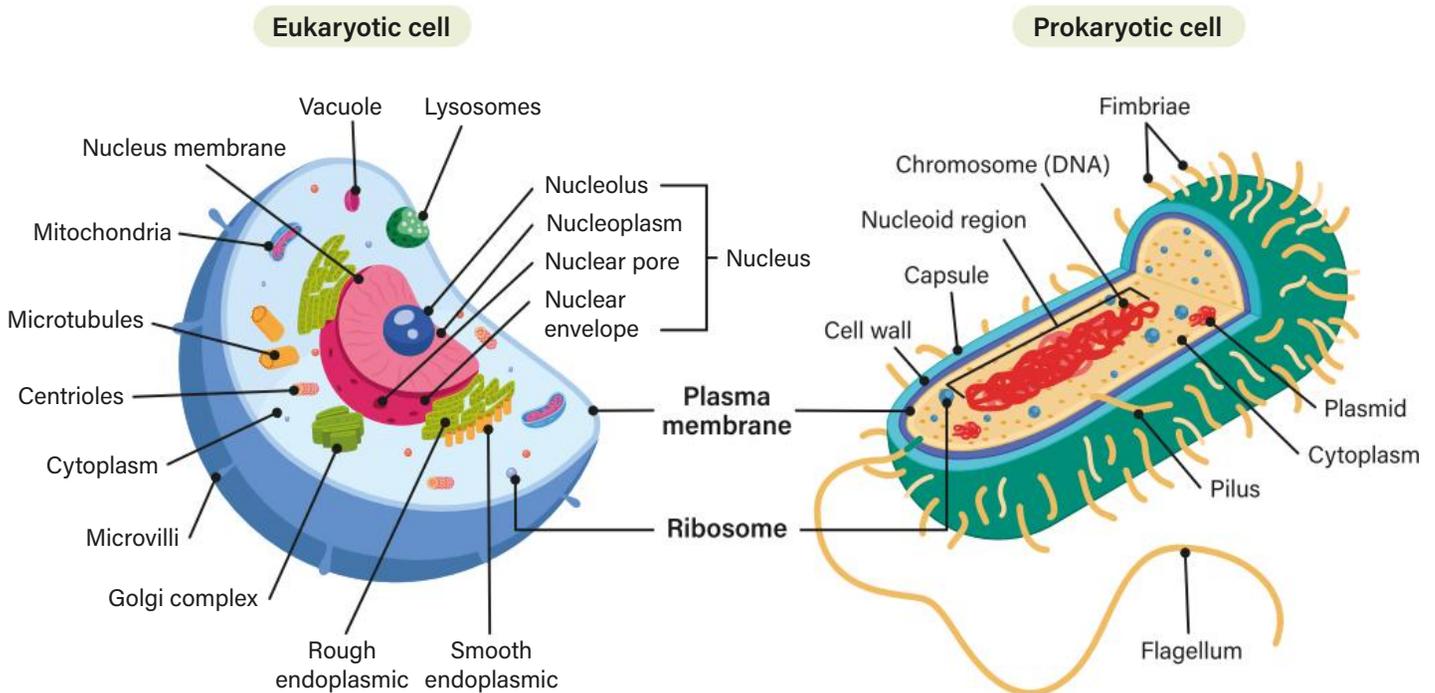
Figure 1.8: ▶
Fungi cells also share features with plant and animal cells.



Bacteria cells are simpler than animal, plant and fungi cells

Bacteria are different from plants, animals and fungi, which are all made of complex **eukaryotic** cells. Bacteria are made of simpler cells, called **prokaryotic** cells. These cells cannot join to form a multicellular organism. Bacteria cells have DNA, but they do not have a nucleus to hold it in place. The DNA floats freely in the cytoplasm. However, there are some similarities between the different cells. Figure 1.9 shows the structure of eukaryotic and prokaryotic cells.

Figure 1.9: The structure of eukaryotic (animal, plant and fungi) cells and prokaryotic (bacteria) cells



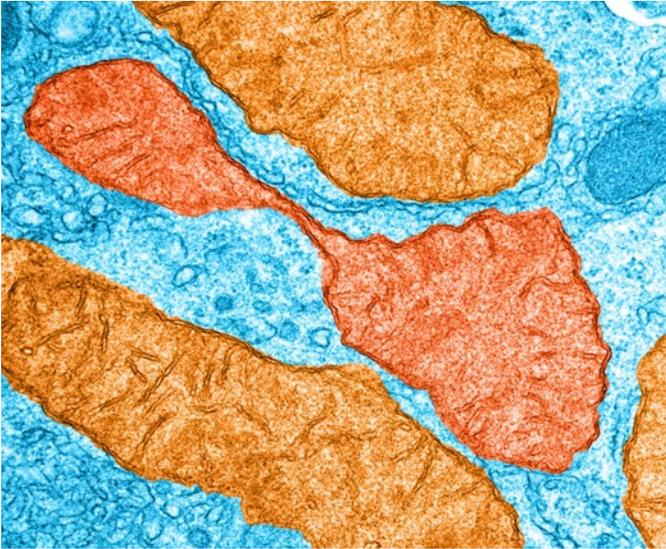
Staining shows the organelles of cells

Scientists use chemicals called stains to artificially colour some of the parts of cells. Staining makes them easier to see under a microscope. In the image shown in Figure 1.7, a purple stain has been used to colour some of the cell parts.

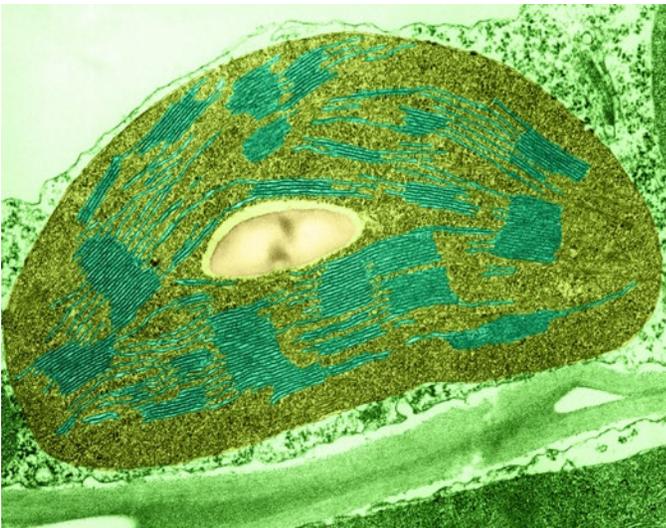
Most cell structures are too small to be seen under a microscope. Parts of a cell that can be seen under a light microscope include the nucleus, cell membrane, cell wall and chloroplast. The cytoplasm cannot really be seen in Figure 1.7, but you can see floating substances: they look like a grainy background inside the cell membrane.

To see the organelles of cells in more detail, scientists use technologies like the electron microscope. These microscopes can produce images of all the organelles contained within cells in great detail. Some examples are shown in Figure 1.10.

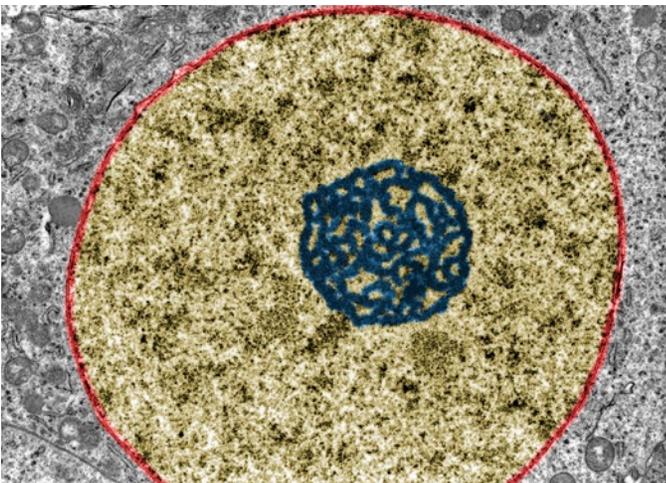
Ⓐ Mitochondria



Ⓑ Cell wall and chloroplast (49 000× magnification)



Ⓒ False-colour nucleus



▲ **Figure 1.10:** Electron microscopes allow scientists to view and understand the structure of cell organelles, which cannot be seen using a light microscope.

Learning Ladder

Cells

- 1 Identify in which cells these organelles are found.
a Nucleus b Ribosomes c Cell wall
d Cell membrane e Vacuole
- 2 Describe the function of the organelles that are common to all living things.
- 3 Identify an organelle that is found in an animal cell but not in a bacteria cell. Explain the function of this organelle.
- 4 Compare the four types of cells from this section – animal, plant, fungi and bacteria – in terms of the organelles they contain.
- 5 Analyse how the organelles discussed in Question 4 contribute to the survival of animal, plant, fungi and bacteria cells.

Nature and development of science

- 1 Identify two technologies that have helped scientists to understand the structure of different cells.
- 2 Describe how chemists and biologists may work together when studying cell organelles. (*Hint:* Think about some of the processes carried out by organelles.)
- 3 Explain how the electron microscope has helped scientists to understand the structure and function of different organelles.
- 4 Discuss how our models of cells may have changed over time, based on the technologies that have become available.

Planning and conducting

p. 236

- 1 Identify two pieces of scientific equipment that you might use when you are conducting a scientific investigation of cells and their organelles.
- 2 Identify two risks associated with using a light microscope. Describe how you could minimise the chance of these risks occurring.

Key idea: Form and function

Consider the structure of some of the plants in your garden. Propose and discuss how their organelles help them to maintain these shapes and structures. Construct a diagram showing the organelles that help to give plants structure.

Success criteria

- I can describe the organelles of plant and animal cells.
- I can compare the features of plant, animal, fungi and bacteria cells.

1.3 ▶ Unicellular and multicellular organisms

Learning intention

At the end of this lesson, I will be able to distinguish between unicellular and multicellular organisms.

Key terms

differentiated cell: a cell that has a specialised function

multicellular: made of more than one cell

protozoan: a unicellular eukaryote that moves and feeds on organic matter

unicellular: made of one cell

Investigation 1.3

Observing unicellular organisms, p. 298

Key idea: Form and function

Figure 1.11: Yeast cells are unicellular organisms.

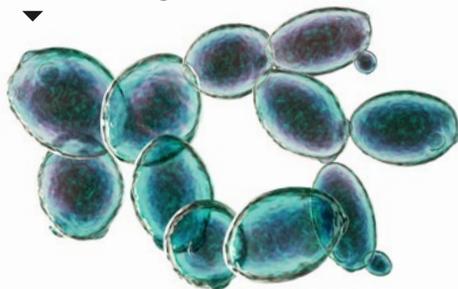
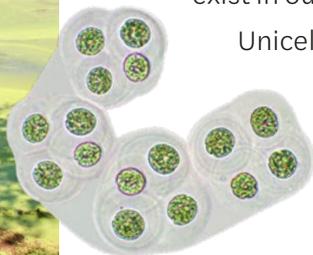


Figure 1.12: Algae blooms consist of millions of independent unicellular organisms that exist side-by-side. These cells can be seen under a microscope.



Organisms can have one or many cells. Single-celled organisms are **unicellular** – *uni* means 'one'. **Multicellular** organisms have more than one (and often many) cells.

Bacteria, and some types of plant and fungi, are examples of unicellular organisms. Multicellular organisms include humans, other mammals, birds, trees and mushrooms. Multicellular organisms are larger and more complex than unicellular organisms.



Figure 1.13: Kookaburras (animals) and eucalyptus trees (plants) are both examples of multicellular organisms that are made up of eukaryotic cells.

Unicellular organisms consist of one cell

Unicellular organisms are microscopic and cannot be seen with the naked eye. In these organisms, all life processes, such as digestion, feeding and reproduction, happen in one tiny cell.

Most unicellular organisms are prokaryotes (see Section 1.2). This means they do not have the same structures as plant and animal cells. There are two kinds of prokaryotes: bacteria and archaeans. Bacteria are found in every environment – a single millilitre of water contains a million bacterial cells. Archaeans are not as common, and many exist in environments we would find hostile, such as hot springs – but they also exist in our own bodies.

Unicellular organisms can also be eukaryotes (see Section 1.2). Eukaryotes have a nucleus and mitochondria, and some have chloroplasts, so they are similar to plant cells.

In fact, some eukaryotes are simple plants, such as green algae. The patches of algae we might see in the wild are actually huge colonies of single-celled plants.

Similarly, yeast is a single-celled fungus.

Prokaryotes and eukaryotes have cell parts that help them to survive and reproduce after they reach a certain size.

Unicellular organisms do not have senses, but they respond to various conditions such as changes in temperature and light, and to touch. Certain eukaryotes, called **protozoans**, can even move, propelling themselves through water or liquid using tiny hair-like or oar-like structures. They use this movement to chase down and digest other microscopic organisms.

Multicellular organisms are made up of many different cells

Most animals, plants and fungi are multicellular organisms. Some are large and some are microscopic, but they all have bodies made up of more than one cell.

Multicellular organisms have hundreds of **differentiated cells** with specific functions. These cells make up organs such as the liver, heart and kidneys, which do different things for an organism's survival.



Figure 1.14: Humans contain many specialised cells, like these red blood cells, which help to carry oxygen and nutrients around the body.

Multicellular organisms have many advantages over unicellular organisms. The main one is that no single cell in a multicellular organism's body has to perform every function needed to survive. This leads to less work and stress for the cells, which means the organism can grow larger and live for longer.

Learning Ladder

Cells

- 1 Identify each of the following organisms as unicellular or multicellular.
 - a Kookaburra
 - b Bacteria
 - c Algae
 - d Humans
- 2 Describe two features of unicellular organisms.
- 3 Explain why differentiated cells are important to multicellular organisms.
- 4 Compare the features of unicellular and multicellular organisms.
- 5 Analyse how the features discussed in Question 4 contribute to the survival of unicellular and multicellular organisms.

Nature and development of science

- 1 Propose a problem that may occur if large organisms like humans were unicellular.
- 2 Describe how scientists from different disciplines could work together to study unicellular and multicellular organisms.

Planning and conducting

p. 236

Read Investigation 1.3 on page 298, then answer the following questions.

- 1 Identify three pieces of scientific equipment that are used in the investigation.
- 2 Describe a risk from this investigation and explain how you would minimise its chances of occurring.
- 3 Identify the:
 - a independent (changed) variable.
 - b dependent (measured) variable.
 - c controlled (kept the same) variables.

Key idea: Form and function

Explain how being made up of multiple cells can help organisms such as plants and animals (including humans) to function and live for longer than unicellular organisms. Use secondary research to help you provide examples for your explanation. Present your findings as a digital infographic.

Success criteria

- I can distinguish between unicellular and multicellular organisms.

1.4 ▶ Chemical reactions in cells

Learning intention

At the end of this lesson, I will be able to explain the processes of photosynthesis and respiration.

Key terms

aerobic respiration: the process of turning glucose into energy where the cells take in oxygen and release carbon dioxide

anaerobic respiration: how living things produce energy without oxygen

chlorophyll: the green pigment in plant cells that absorbs sunlight and enables photosynthesis

glucose: a type of sugar that is the energy source for cells

photosynthesis: the chemical reaction, powered by sunlight, in plants that converts carbon dioxide and water into sugar and oxygen

respiration: a chemical reaction that converts glucose to energy

stomata: pores on the surface of a leaf; the site of gas exchange in plants

Investigation 1.4A

Investigating respiration, p. 299

Investigation 1.4B

Energy from food, p. 301

Key idea: Form and function

Animals and plants have many cells that carry out various functions to help the organism survive. To perform these functions, cells need a constant supply of energy. Animal cells get their energy from food, and plant cells make their food using sunlight.

All cells need energy to survive

Without a continuous supply of energy, cells cannot perform important functions and will die. The only type of energy that cells can use is chemical energy. Chemical energy comes from **glucose**, which is a type of sugar. Plant cells convert energy from the Sun into glucose. Animal cells get most of their energy from food.

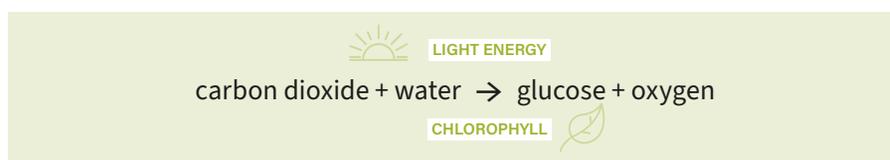
▲ **Figure 1.15:** Plant cells get energy from sunlight.

Photosynthesis is how plants make food

Plants rely on a chemical reaction called **photosynthesis** to make their food. **Chlorophyll** (a green pigment) in the chloroplasts of plant cells absorbs sunlight and uses it to convert carbon dioxide and water into glucose and oxygen. The process of photosynthesis is summarised in Figure 1.16 and shown in Figure 1.17.

The glucose produced from this reaction is either used in respiration or stored for later use. The oxygen moves into the environment through special pores (openings) in the leaves called **stomata**, or is used during respiration.

We breathe in oxygen released by plants, and consume glucose made in leaves. If plants did not exist, humans would not exist either!



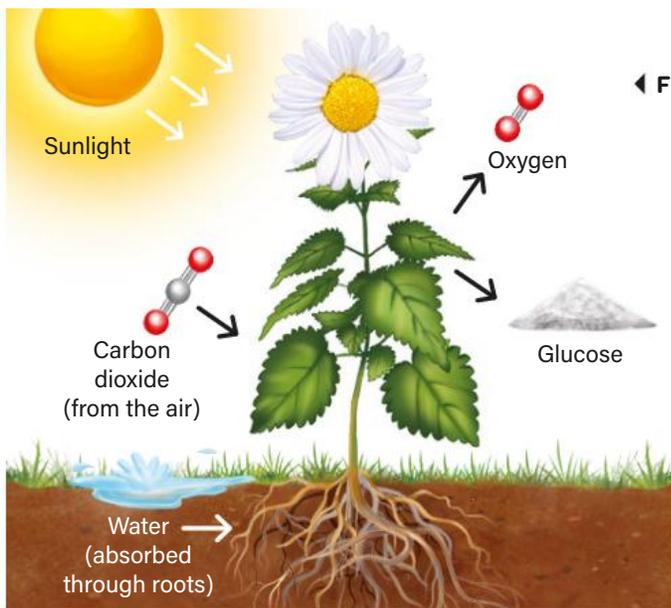
▲ **Figure 1.16:** The process of photosynthesis

Respiration is how cells make energy

Respiration is a chemical reaction that converts glucose to carbon dioxide and produces energy. Respiration occurs in all cells. There are two forms of respiration:

- **aerobic respiration**, which uses oxygen
- **anaerobic respiration**, which happens without oxygen.

Aerobic respiration provides animals and plants with most of their energy. In animals, aerobic respiration involves the organism taking in glucose (from food) and oxygen (from the environment via lungs in humans). The glucose and oxygen combine to form carbon dioxide, water and energy.



◀ **Figure 1.17:** Photosynthesis happens in the leaves of plants.

The chemical energy produced is transported to the cells that need it, while the carbon dioxide and water are removed from the cell. This process is summarised in Figure 1.18.



▲ **Figure 1.18:** The process of aerobic respiration

Respiration happens in mitochondria

Respiration happens in organelles (cell structures) called mitochondria, in both plant and animal cells. Mitochondria are called the ‘powerhouse’ of cells because they take in nutrients, break them down, and change them into energy that cells can use. Animals and plants do not respire in the same way, and they gain energy from different nutrients, but mitochondria have the same purpose in all living things.

Mitochondria are very small. Some cells have several thousand mitochondria because they need lots of energy – for example, muscle cells in animals. Other cells have lower energy needs, so they have few or no mitochondria.



▲ **Figure 1.19:** Mitochondria are the organelles responsible for respiration. Because their folded structure provides a lot of surface area, many reactions can occur at the same time.

Learning Ladder

Cells

- 1 Identify a structure of plants that allows them to gain each of the following materials needed for photosynthesis.
 - a Water
 - b Carbon dioxide
 - c Light energy
- 2 Describe the structure that enables photosynthesis to occur.
- 3 Explain why both chloroplasts and mitochondria are necessary in plant cells.

Use and influence of science

- 1 Propose a socio-scientific issue that is linked to removing plants from the environment.
- 2 Describe how our knowledge of photosynthesis may influence the type of research scientists conduct into how oxygen is produced.

Planning and conducting

p. 236

Read the aim, materials and method of Investigation 1.4B on page 301, and then answer the following questions.

- 1 Identify the correct way to secure the test tube over the food.
- 2 Identify two hazards associated with this investigation. Outline how you could minimise the risk of harm occurring.
- 3 Identify the independent and dependent variables of the investigation.
- 4 Propose two ways that you could make sure that the data you collect from this investigation is precise.
- 5 Investigate a different independent or dependent variable, and construct a safe and ethical step-by-step method.

Key idea: Form and function

Consider the diagram of the mitochondria organelle in Figure 1.19.

- a Explain how its structure enables it to carry out its function of respiration within cells.
- b Propose three cell types that may require large numbers of mitochondria. Justify your choices.

Success criteria

- I can explain the processes of photosynthesis and respiration.

1.5 ▶ Cells are the building blocks of life



Figure 1.20: This tissue is in the human brain; it is called neuroglia ('nerve glue').

Learning intention

At the end of this lesson, I will be able to:

- examine cells as the basic unit of life
- describe the relationships between cells, tissues and organs that make up living things.

Key terms

differentiate: to change so as to have a particular function

organ: a structure made up of two or more tissues that has a specific function

Key idea: Form and function

All living things are comprised of one or more cells. Within multicellular organisms, this means that cells must differentiate so that the organism can survive.

Specialised cells perform specific tasks

A multicellular organism starts as a single cell. This one cell divides into many cells that are joined together. As the organism grows and more cells form, the cells **differentiate** and perform different functions to help the organism work effectively. Some of the specialised cells in plants and animals are listed in Table 1.1.

Table 1.1: Some of the specialised cells in plants and animals

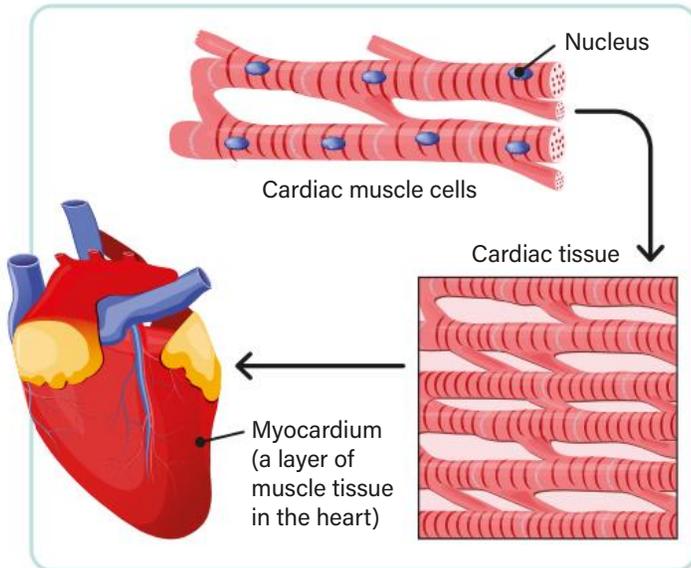
Organism	Specialised cell	Function
Human	Epidermal cell	Forms a protective outer layer (skin)
	Nerve cell	Transmits messages around the body
	Red blood cell	Transports oxygen and nutrients around the body
Plant	Palisade cell	Contains chlorophyll to carry out photosynthesis
	Xylem cell	Transports water from the roots to the stem and leaves
	Phloem cell	Transports sugar around the plant

Specialised cells can form tissues and organs

Cells that specialise in the same function can group together to form tissues and **organs**. These structures are larger and more complex than individual cells. Tissues and organs are structured in specific ways to help organisms function efficiently. The flowchart in Figure 1.21 summarises the levels of organisation in organisms. Figure 1.22 shows an example.

organelle → specialised cell → tissue →
organ → organ system → organism

▲ **Figure 1.21:** The process of forming tissues and organs



▲ **Figure 1.22:** The heart is an organ that has a muscular layer of tissue called the myocardium. The myocardium is made of cardiac tissue, which in turn is made of cardiac muscle cells.

Scientists use microscopes to learn about specialised cells

As cells are too small to be seen by the naked eye, scientists use microscopes to view them and make observations. When viewing samples of tissues made of specialised cells, scientists will often use electron microscopes rather than light microscopes. This is because these microscopes have a higher magnification that can be used to identify the number and arrangement of different organelles within the cells. Scientists can use these observations to help them understand the roles of different types of specialised cells, tissue and organs in multicellular organisms.

Figure 1.23:

Scientists need to use microscopes to see specialised cells.



Learning Ladder

Cells

- 1 Identify a specialised cell found in:
 - a humans.
 - b plants.
- 2 For the cells you identified in Question 1a, describe their structure and function.
- 3 Explain how specialised cells form the basis of more complex structures in multicellular organisms.
- 4 Compare the complexity of a cell organelle to an organ in a human body.
- 5 Evaluate the following statement:
Organelles enable the survival of cells, like cells enable the survival of humans.

Use and influence of science

- 1 Identify an issue scientists may face when trying to work with and understand the cells of humans.
- 2 Propose and describe how our knowledge of human cell structures may benefit the medical industry.
- 3 Explain an ethical consideration that would need to be addressed before scientists conducted studies relating to cells on living humans.

Questioning and predicting

p. 232

- 1 A student wanted to investigate the effect of temperature on the brain (an organ made of neural tissue). Which of the following would be an appropriate question for their investigation?
 - A Does heat hurt the brain?
 - B Does heat damage neural tissue?
 - C How does temperature affect a human brain?
- 2 Predict which of the following tissues would contain cells with the most mitochondria, based on your knowledge of cells and organelles.
 - A Skin tissue
 - B Intestinal tissue
 - C Muscle tissue
- 3 Use your answer in Question 2 to construct an appropriate scientific question and prediction about which tissue type contains the most mitochondria.

Key idea: Form and function

Consider Figure 1.22. Explain how the form and alignment of cardiac cells allow the tissue of the heart to effectively provide blood to the body. Use secondary research to help you with your response.

Success criteria

- I can state how cells, tissues and organs are related.
- I can describe how scientists make observations about cells, tissues and organs.

1.6 ▶ Key idea: Form and function

Learning intention

At the end of this lesson, I will be able to:

- relate the structure and properties of new stem cells to their function in medical research
- explain the importance of stem cells within multicellular organisms.

Key terms

embryonic stem cell: an undifferentiated cell that is collected from an embryo

generate: produce

perinatal: the time and areas around birth

stem cell: an undifferentiated cell that occurs throughout the body and is able to divide and form new identical copies of itself

undifferentiated: has not changed from its original form

Key idea: Form and function

All multicellular organisms start their life as a single cell. This one type of cell is what allows all of the specialised cells in your body to form. But what is this cell, and how does its form relate to its functions, both in the body and in medical research?

Stem cells are present in all multicellular organisms

Stem cells are **undifferentiated** cells that occur all throughout the body. These cells are able to divide and form new identical copies of themselves. This ability to **generate**, and the lack of specialisation, is what makes stem cells unique within multicellular organisms. One of the most important types of stem cells are **embryonic stem cells**. These are the undifferentiated cells present within a new organism such as a human embryo that divide and develop so that the baby can grow and develop vital tissue and organ structures within the body.

Differentiated cells form from stem cells

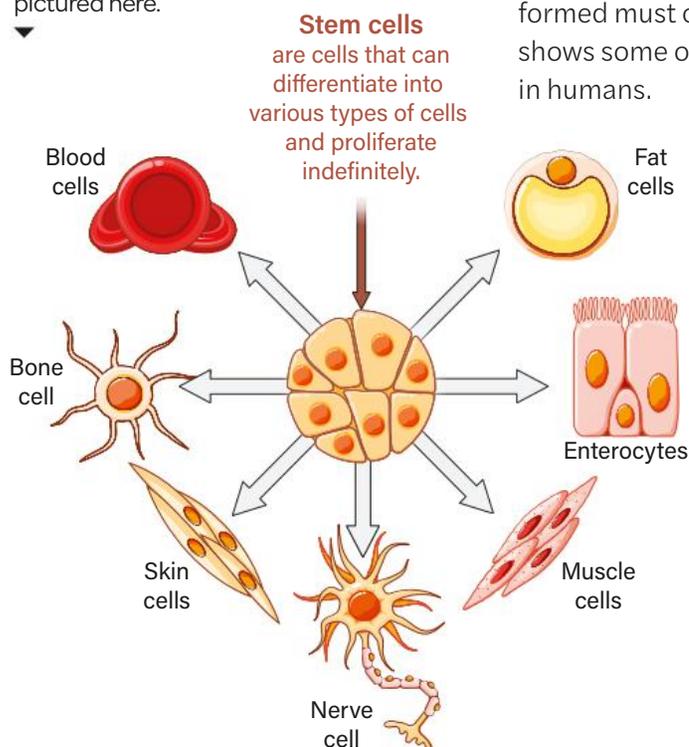
Once embryonic stem cells have started dividing, they differentiate as the embryo develops. Stem cells around the embryo 'switch on' parts of their code from their DNA and form new, specialised cells like muscle cells, nerve (neural) cells and skin (epithelial) cells. Once these cells have formed, many lose their ability to divide. This means any new cells formed must come from stem cells that remain in the body. Figure 1.24 shows some of the specialised cells that can form from stem cells in humans.

Stem cells used in medical research

The ability of stem cells to generate new cell types makes them highly desirable in the medical field. Scientists have been studying stem cells since the 1950s, with their first documented use being in 1956. Scientists studying stem cells can use:

- **embryonic stem cells:** stem cells that have been taken from a developing embryo.
- **adult stem cells:** stem cells donated by adults from their body tissue, which can sometimes be converted back into stem cells with embryonic properties, allowing wider research to be conducted
- **perinatal stem cells:** stem cells collected from the amniotic fluid or umbilical cord of babies.

Figure 1.24: Stem cells differentiate when parts of the code in their DNA 'switch on', causing them to divide and form specialised cells, such as the ones pictured here.



Once scientists have the stem cells, they can culture (grow) them in a laboratory and use them to:

- understand how diseases occur
- generate new healthy cells
- conduct drug testing.

Using this research, doctors have already begun using stem cells. Patients undergoing chemotherapy have received bone marrow transplants of stem cells that will differentiate into bone tissue and blood cells. This helps to re-establish their immune system and blood supply.

Future uses of stem cells need to be carefully considered

The most effective scientific research is conducted using embryonic stem cells, as they have the best generation ability and can differentiate into many different cell types. However, these cells need to be collected directly from developing embryos, which some people consider unethical. Scientists collect these cells in labs, from embryos that have been produced but not placed into a mother to develop into a baby. These embryos are only kept after informed consent has been obtained from the donors.

Another issue is guiding stem cells to produce the cell types that scientists want to study. Sometimes, stem cells will randomly start differentiating into a cell type that is different from what scientists are trying to study. Scientists are working on ways to avoid this occurring.

The future of stem cells is filled with possibilities. Scientists are currently working on using stem cells to build new muscle tissue and organs from a person's own cells to replace their own damaged tissue and organs. Continued research may one day make such treatments a reality.



Figure 1.25: Individuals can donate blood to provide stem cells for research.

Learning Ladder

Cells

- 1 Identify three cells that can form from stem cells.
- 2 Describe the features that are unique to stem cells.
- 3 Explain why stem cells are important in developing embryos.
- 4 Compare the structure of a stem cell to a specialised cell such as a muscle cell.
- 5 Analyse the importance of stem cells in maintaining the function of multicellular organisms.

Use and influence of science

- 1 Identify a socio-scientific issue in stem cell research.
- 2 Describe how scientists' knowledge of stem cells has already impacted the medical field.
- 3 Explain an ethical consideration that may impact research into stem cells.
- 4 Discuss how scientists might respond if they had to stop all their research immediately because of the backlash against such research.
- 5 Investigate and analyse how real scientists have responded to situations similar to the one discussed in Question 4.

Questioning and predicting

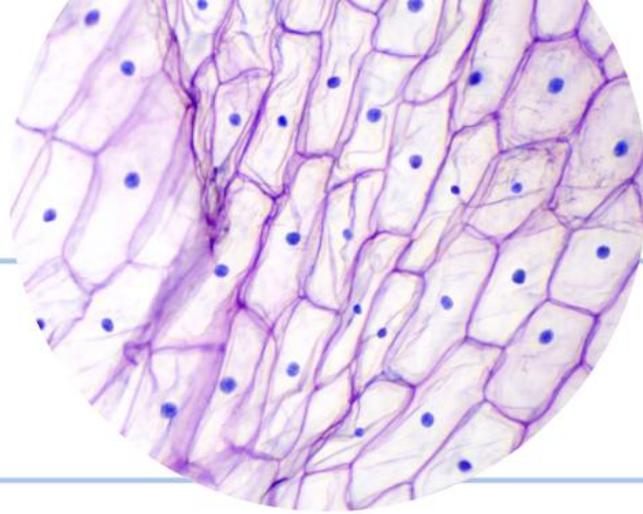
p. 232

- 1 From the following, identify an appropriate question that scientists could use to investigate stem cells.
A How does the type of stem cell affect its ability to differentiate?
B Are there different types of stem cells?
C How does society want stem cells to be used?
- 2 Based on the information in this section, make a prediction about the answer to the question you selected in Question 1.
- 3 Think about some of the uses of stem cells. Construct a scientific question you could ask to help scientists research a specific use of stem cells in medicine.
- 4 Use secondary research to examine your scientific question and construct a hypothesis stating what you think will be the outcome of the research.
- 5 Evaluate your hypothesis to determine if the relationship between the independent and dependent variables is valid.

Success criteria

- I can relate the structure and properties of stem cells to their function in medical research.
- I can explain why stem cells are important in multicellular organisms.

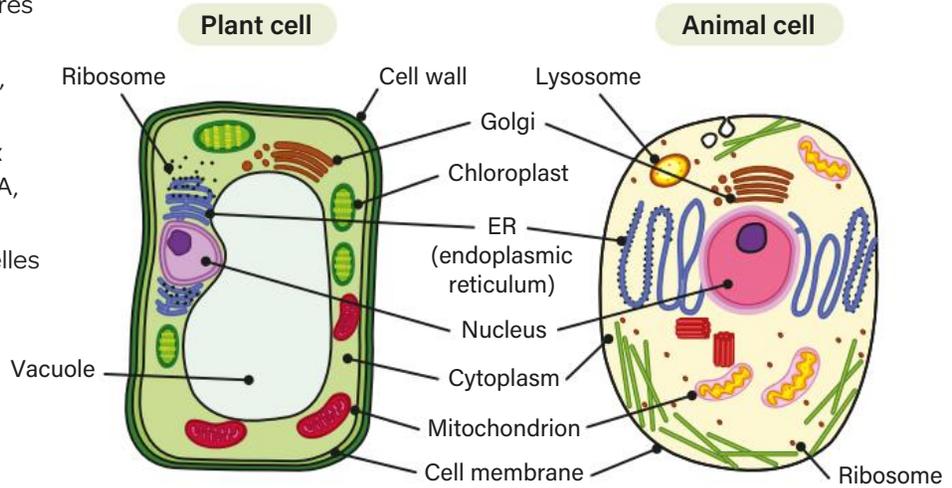
► Summary



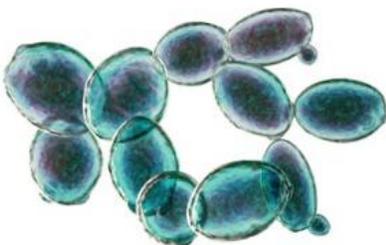
Cell theory is a theory proposed by Theodor Schwann, which can be summarised as follows:

- All organisms are made of cells.
- Cells are the basic units of life.
- Cells come from pre-existing cells that have multiplied.

- Cells contain specialised structures so that they can function.
- All cells contain a cell membrane, cytoplasm, ribosomes and DNA.
- Eukaryotic cells contain complex organelles like nuclei to store DNA, mitochondria and vacuoles.
- Prokaryotic cells have the organelles common to all cells, but do not have complex organelles.
- Plant cells have a cell wall for structure and chloroplasts to produce glucose.



- Unicellular organisms are organisms that are composed of a single cell. They can be prokaryotic or eukaryotic.
- Unicellular organisms include bacteria, some fungi (like yeast) and algae.
- Multicellular organisms are made up of many specialised cells. All multicellular organisms are eukaryotic.
- Multicellular organisms include humans, some fungi (like mushrooms) and plants.



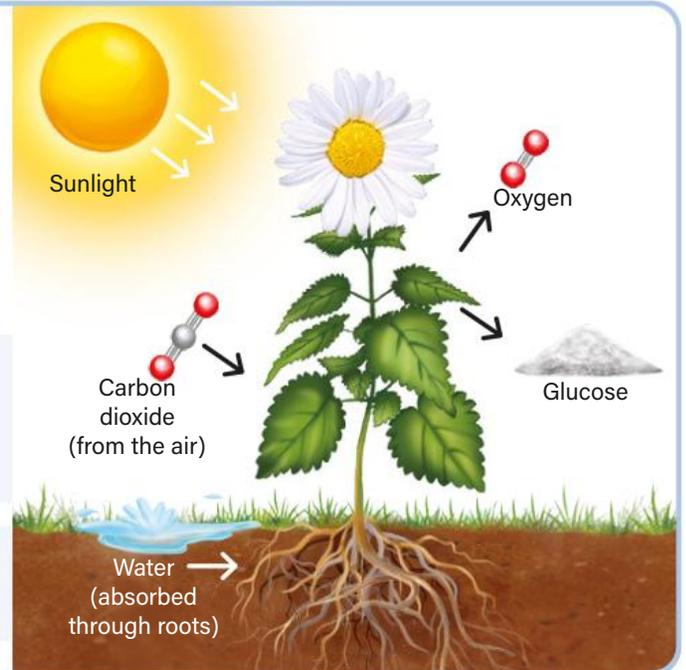
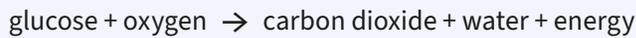
- Photosynthesis uses heat energy from the Sun, carbon dioxide from the air, and water from the ground to produce glucose.
- Plants photosynthesise, which is how all other living things have oxygen to breathe!
- Respiration occurs in the mitochondria of multicellular organisms and uses glucose and oxygen to produce ATP energy.



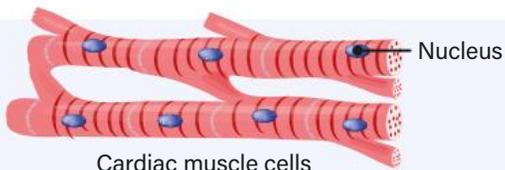
LIGHT ENERGY



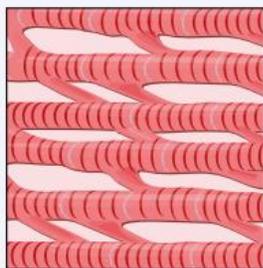
CHLOROPHYLL



- Multicellular organisms contain differentiated cells, which have specialised to perform specific roles.
- Specialised cells form tissue, which in turn forms organs within multicellular organisms.
- Scientists use microscopes to view and learn about all different types of cells.



Cardiac muscle cells



Cardiac tissue

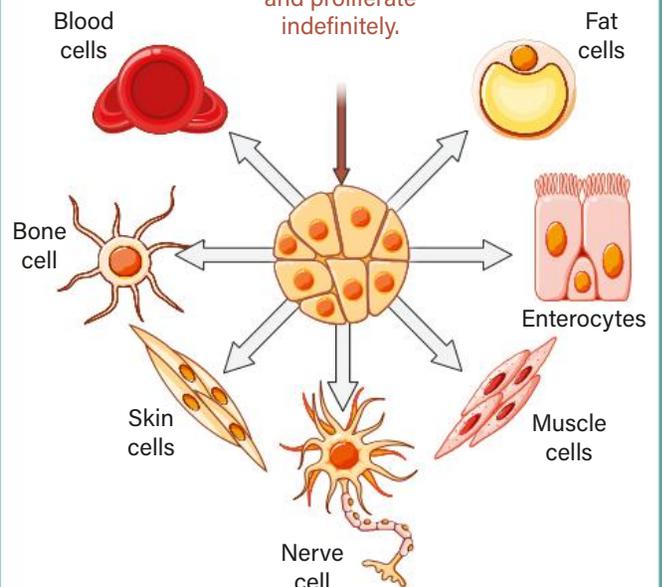


Myocardium
(a layer of muscle tissue in the heart)

Key idea: Form and function

- Stem cells are undifferentiated cells that can replicate themselves and become specialised.
- Scientists are using stem cell research to try to produce new cells that can replace diseased ones in human bodies.

Stem cells are cells that can differentiate into various types of cells and proliferate indefinitely.



Masterclass

Steps in progression

1

2

Science understanding	Cells	Identify three features of stem cells.	Describe two functions of neural cells.
Science as a human endeavour	Nature and development of science	Propose one problem with creating brain organoids from stem cells.	Describe why Dr Lancaster may have needed biologists, chemists and medical doctors on her research team.
	Use and influence of science	Propose a socio-scientific issue linked to research on the human brain.	Describe how our knowledge of brain disorders may impact society.
Science inquiry	Questioning and predicting	True or false? <i>'How does the development level of a brain impact its response to microcephaly?' is a scientific question.</i>	Make a prediction about the level of use of stem cells in scientific research over the next 20 years.
	Planning and conducting	Identify two pieces of scientific equipment Dr Madeline Lancaster's team would have used while conducting their research.	Describe three ways that the research team could have minimised their risk of harm during their investigations.

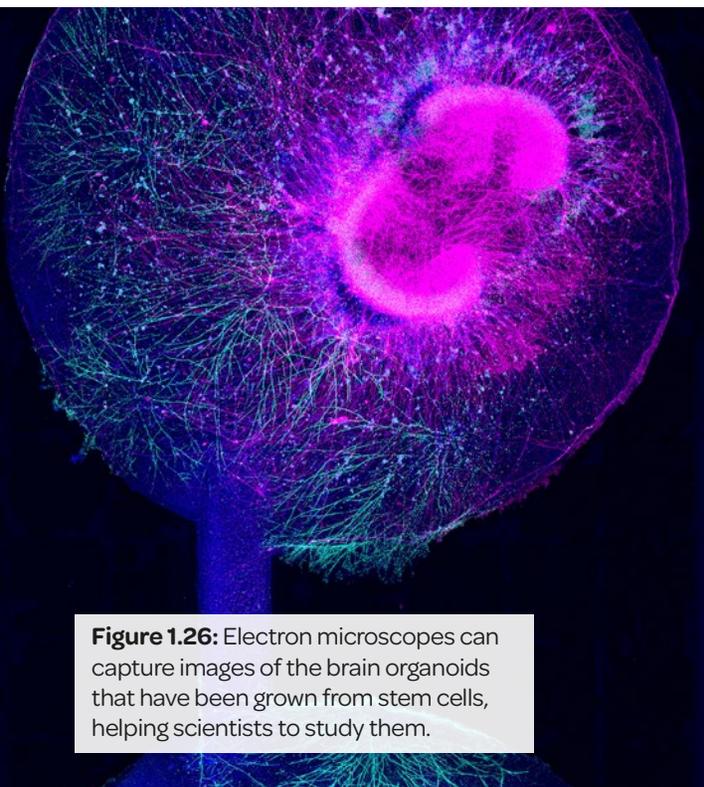


Figure 1.26: Electron microscopes can capture images of the brain organoids that have been grown from stem cells, helping scientists to study them.

Using stem cells to grow brains

Undifferentiated stem cells are the focus of a lot of medical research so that scientists can see what medical problems they are able to solve. However, even more interesting is the fact that scientists are actually starting to grow human organs using stem cells!

Scientists in the United Kingdom, led by biologist Dr Madeline Lancaster, have been able to use stem cells to grow and shape neural tissue into primitive versions of human brains (called organoids)! They achieved this by setting up stem cells in a 3D system and then guiding the cells to differentiate into neurons.

Setting up and growing stem cells into brain organoids in this way will help scientists to research and understand conditions that affect the human brain. Research conducted on the organoids has already provided better data than studies conducted on mice for the condition microcephaly (babies whose heads are too small for their overall size). Perhaps, one day, these neurons could even be used to help replace damaged brain cells in humans!

Demonstrate your understanding

3

4

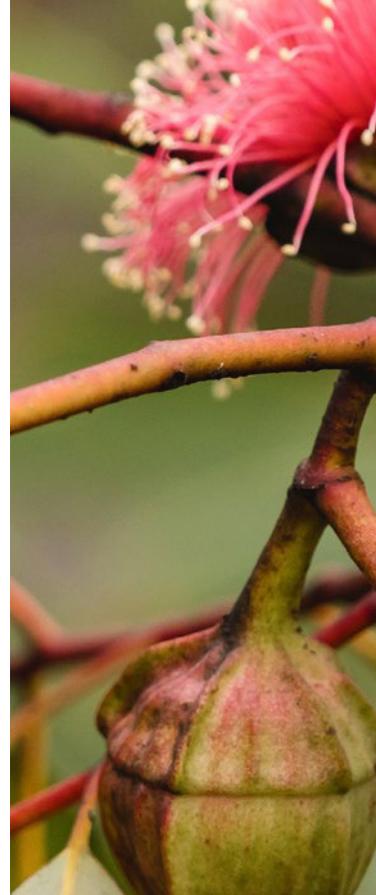
5

<p>Explain the role of stem cells in producing the cells needed to form the brain.</p>	<p>Use the information below and secondary research to compare stem cells and neural cells in terms of their form and function.</p>	<p>Analyse how the structure of specialised cells in multicellular organisms helps them to survive.</p>	
<p>Explain how the research team's work has led to new understanding of the human brain.</p>	<p>Discuss how our ability to model the brain has developed over time. <i>(Hint: Consider different technologies.)</i></p>	<p>Analyse how researchers from different countries would be able to work together on stem cell projects like Dr Lancaster's.</p>	
<p>Explain an ethical consideration required when transferring knowledge from Dr Lancaster's research to real patients.</p>	<p>Discuss the potential impacts of being able to use brain-like organoids rather than laboratory mice in scientific research.</p>	<p>Analyse how the use of stem cells to grow organoids for study may shape regulations around scientific testing of products.</p>	
<p>Construct a scientific question that you could use to test your prediction from step 2.</p>	<p>Develop a scientific hypothesis that relates to your scientific question from step 3.</p>	<p>Evaluate your scientific question and hypothesis for their scientific validity.</p>	<p>Science how-to p. 232</p>
<p>Identify three variables that would need to be controlled when using stem cells to research brain conditions like microcephaly.</p>	<p>Propose and discuss how the research team could ensure that the data they collected on microcephaly was recorded precisely.</p>	<p>Use secondary research to help you design an investigation that could be conducted by Dr Lancaster's team on a specific brain condition. Be sure to include safety, ethical and procedural factors.</p>	<p>Science how-to p. 236</p>

Figure 1.27: Scientists use mice a lot when studying the impact of diseases on humans, but using stem cells often provides better data.



2.0 Systems of living things



In multicellular living organisms, cells, tissues and organs form complex systems with specialised functions. The systems of living things work together so that plants and animals can survive, by gaining energy and other required products, transporting them to new places for use, and removing waste products that might otherwise cause harm. In this chapter, you will learn how systems in plants and animals function normally to enable survival, and how they can be affected by a variety of factors that the organism may or may not control.

Learning Ladder

The Learning Ladder for each chapter maps the Science Understanding, Science as a Human Endeavour and Science Inquiry strands that will be covered. Each ladder has five levels of progression, called steps. To climb the ladders, you need to develop fluency at each step. This will help you develop the ability to complete tasks that are more complex.

5	I can analyse the relationship between structure and function at organ system levels	I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations
4	I can discuss the effects of disorders in the cells, tissues or organs of systems	I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues
3	I can explain how organ systems work together to enable survival	I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances
2	I can describe how cell-based structures work together to carry out specialised functions	I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society
1	I can distinguish between cells, tissues, organs and organ systems	I can recognise scientific problems and solutions	I can identify socio-scientific issues
Steps in progression	Biological science: Systems of living things	Nature and development of science	Use and influence of science
	Science understanding	Science as a human endeavour	



Figure 2.1: These flowers from *Corymbia calophylla* are part of a living system that relies on organs working together to maintain life.

I can evaluate investigation questions and predictions for scientific validity	I can communicate scientific findings and arguments for specific purposes to specific audiences	5
I can develop a hypothesis that predicts the relationship between investigation variables	I can use digital technologies to organise and communicate data and information	4
I can construct questions and predictions to investigate scientific problems	I can prepare a variety of representations to communicate ideas and findings	3
I can make simple predictions based on what I know and observe	I can select appropriate formats to communicate ideas and findings	2
I can recognise questions that can be investigated scientifically	I can identify scientific terminology used to communicate information	1
Questioning and predicting	Communicating	Steps in progression
Science inquiry		

2.1 ▶ Organ systems basics

Learning intention

At the end of this lesson, I will be able to explain the interrelationships between cells, tissues and organs.

Key terms

cell: the smallest functional unit of an organism

differentiate: to change so as to have a particular function

organ: a structure made up of two or more tissues that has a specific function

organ system: two or more plant or body organs that are connected and working together

organism: an individual animal, plant or other living thing

stem cell: an undifferentiated cell that can develop into various types of cells

tissue: a group of cells with a similar structure and function

Key idea: Systems

In **organisms** made of more than one **cell**, cells with similar functions group together to form tissues, organs and **organ systems**.

Cells can perform different jobs

In unicellular organisms, the single cell must carry out all the major life functions. In multicellular organisms, the cells share the workload, and different cells have different functions.

Before an organism starts to develop, its cells are not specialised. These cells are called **stem cells**. As an organism grows, the cells **differentiate** and specialise to carry out different functions.

Tissue is a group of specialised cells

Cells that specialise in the same function group together to form **tissue**. There are four main types of tissue in animals:

- **Epithelial tissue** forms the skin, as well as the body's inner linings.
- **Connective tissue** transports substances (such as nutrients) to where they are needed.
- **Muscle tissue** contracts and relaxes to carry out different functions.
- **Nerve tissue** transmits information between the brain and other organs.

Cells work together as tissues, organs and systems

Different tissues that work together can form **organs**. Tissue systems in plants that perform important functions but do not combine to form organs are discussed in Section 2.7. Two or more organs that are connected and working together form a plant or body system. The organs and tissues in each system are specialised to perform specific roles.

Organs perform an organism's main functions

The brain, heart, kidneys, liver and lungs are the main organs of the human body. Each organ has a specific function; Figure 2.3 shows how an organ system is formed.

Each organ has a different structure. For example, in the heart, epithelial tissue lines the blood vessels. Connective tissue forms the valves of the heart and is in the walls of the blood vessels. Nerve tissue inside the heart controls the beating of the heart muscle, which pumps the blood out of the heart. All these tissues work together to keep the heart working efficiently.

Figure 2.2: Muscles are made up of cells that are specialised to contract and relax.

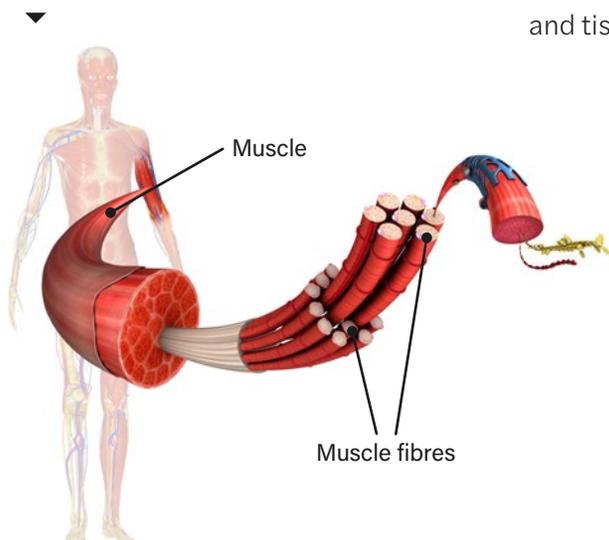
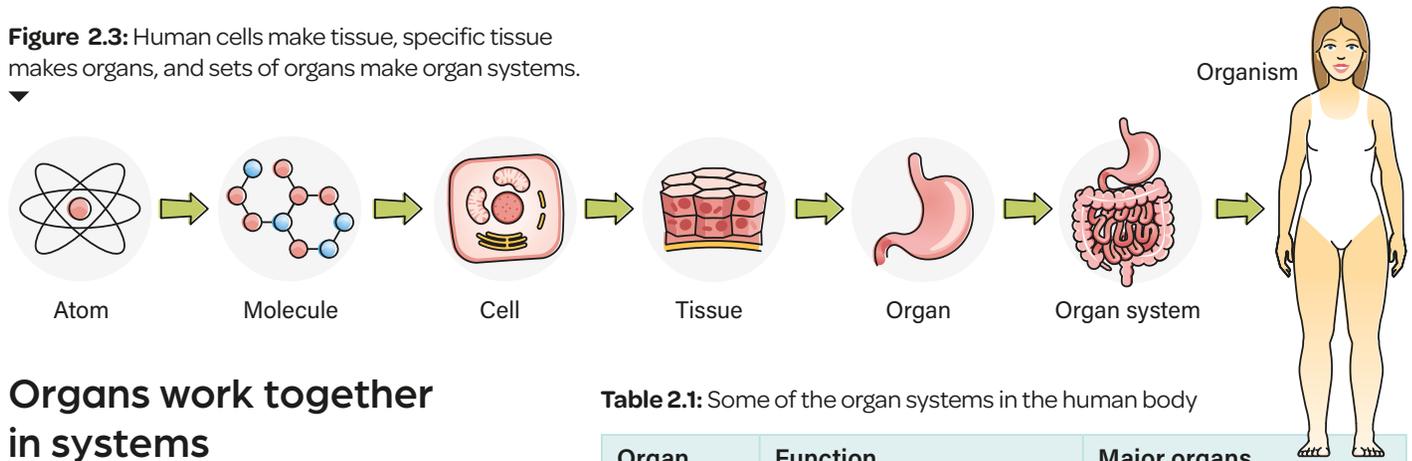


Figure 2.3: Human cells make tissue, specific tissue makes organs, and sets of organs make organ systems.



Organs work together in systems

An organ is not useful on its own. In an organism, each organ is part of a system, along with other necessary tissue such as blood. An organism’s different organ systems work together so that it can function. The human body has several different organ systems, each with its own function and purpose. Table 2.1 summarises the body’s organ systems that will be explored in detail across Sections 2.2 to 2.5.

Table 2.1: Some of the organ systems in the human body

Organ system	Function	Major organs and tissues
Digestive	Breaks down food so nutrients can be absorbed	Oesophagus, stomach, liver, large and small intestines
Respiratory	Allows exchange of gases	Lungs, trachea, larynx, nasal passages
Circulatory	Transports oxygen and nutrients to cells	Heart, blood
Excretory and urinary	Removes waste formed from digestion	Kidneys, ureters, urethra, bladder

Learning Ladder

Systems of living things

- Order these terms from the smallest to the largest structure: tissue, cell, system, organ.
- Classify each of the following as a tissue or an organ, and provide a reason for each response.

a Lungs	b Heart	c Blood
d Muscle	e Brain	f Skin
- Explain the difference between an organ and a tissue, with reference to examples from this section.

Nature and development of science

- True or false?
 - Problems with the heart are related to problems with the circulatory system.*
 - Organs are not related to an organism’s main functions.*
- Propose why a microbiologist might need to work with a physiotherapist to learn about muscular tissues.

Communicating

p. 255

- Identify four terms that could be used to describe tissue in multicellular organisms.
- Describe some ways you could show or represent the tissues in the heart to communicate how it works.

- Figure 2.2 is a diagram of cells that make up muscles. Outline the advantages and disadvantages of using an image like this one to present information about body systems.
- Investigate the nervous system and construct a digital diagram like Figure 2.2 to show the organisation of cells in the nervous system. Include and label nerve cells, neural (brain) tissue, the brain and the nervous system (brain and spinal cord).
- Adapt your response to Question 4 into a clear and simple presentation suitable for an audience of primary school children.

Key idea: Systems

Conduct research online to address the following:

- An organ is a type of system made up of tissues. Construct a list of the organs that are made up of each of the four types of tissues (epithelial, connective, muscle, nerve tissue).
- Discuss what each list of tissues or organs has in common in relation to the structure and function of the system.

Success criteria

- I can explain the interrelationships between cells, tissues and organs.

2.2 ▶ The digestive system

Learning intention

At the end of this lesson, I will be able to:

- identify the role of the human digestive system and name the major organs in this system
- describe how the structures and specialised features and cells of the digestive system enable it to carry out its functions.

Key terms

bile: a salty solution stored in the gallbladder, which aids digestion in the upper small intestine

chemical digestion: breaking down food in a chemical reaction that forms new molecules

chyme: a soupy mixture of partially digested food in the stomach and small intestine

digestion: the physical and chemical processes that break down food in the body

enzyme: a substance that enables or speeds up a chemical reaction

mechanical digestion: physically breaking down food into smaller pieces

peristalsis: the involuntary muscle action that pushes food through the digestive tract

villi: the tiny finger-like projections that line the walls of the small intestine

Key idea: Systems

The role of the human digestive system is to obtain nutrients and energy from food. Our bodies need nutrients to be delivered in a certain way so that our cells can absorb them. The digestive system breaks down food both physically and chemically to allow nutrients to be absorbed into the body.

The digestive system breaks down food

Humans need to consume food to obtain nutrients. Nutrients are essential for energy production, growth, tissue repair and all other cellular processes. However, food cannot move directly into the cells. It first needs to be broken down into smaller molecules during **digestion**.

Digestion happens in two ways:

- **mechanical digestion:** food is physically broken down into smaller pieces (e.g. by chewing) but the food material has not changed into new substances
- **chemical digestion:** digestive **enzymes** trigger chemical reactions, which break down large food molecules into new, smaller molecules that can be absorbed by the body's cells.

In the mouth, food is physically broken into small pieces by the teeth and mixed with saliva, which contains enzymes that chemically break down complex carbohydrates into simple sugars. When you swallow, this mix of food and saliva moves down into the oesophagus and then to the stomach.

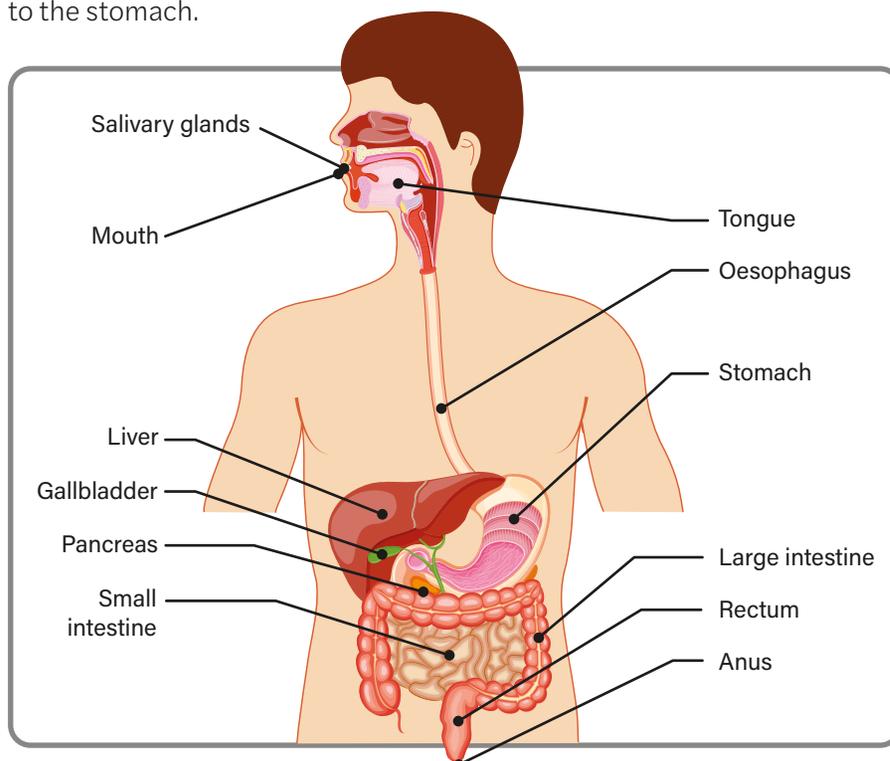


Figure 2.4: Digestion ▶ takes about 24 hours and involves many processes and organs.



Figure 2.5: The digestive system breaks down food to get the essential nutrients.

Within the stomach, the food is broken down further and combined with gastric juices that contain enzymes and hydrochloric acid. This soupy mixture (called **chyme**) is slowly released into the top section of the small intestine. Here, the chyme mixes with **bile** – a salty solution stored in the gallbladder – and pancreatic juices, which both contain more enzymes to chemically break down and neutralise the chyme.

As this mixture moves through the small intestine, the nutrients begin to be absorbed and sent around the body via other body systems. A lot of what we eat is left undigested as it passes through the small intestine; some nutrients are absorbed, but much of the material remains. This moves into the large intestine, also known as the bowel, where bacteria act on it, releasing important vitamins and minerals that can be absorbed and producing gas as a by-product.

Although water can be absorbed in the stomach and small intestine, the remaining absorption of water happens in the large intestine. The remaining solid waste collects in the rectum and is finally expelled as faeces.

The action that keeps things moving down your digestive tract is called **peristalsis**. Peristalsis is an involuntary muscular movement that creates wave-like contractions through your digestive tract. Once you have swallowed your food, peristalsis keeps it moving down your oesophagus and into your stomach.

When your stomach ‘gurgles’ after eating, this is peristalsis accompanied by abdominal noises as food is squeezed from your stomach into the small intestine.

The epiglottis is a specialised component of the digestive system

The epiglottis is a flap of tissue in the throat (see Figure 2.6). The epiglottis covers the trachea (also called the airway) when we swallow so that food can pass into the oesophagus. Although it is not directly involved with the breakdown or absorption of food, without the epiglottis, food would be able to enter and block the airway.

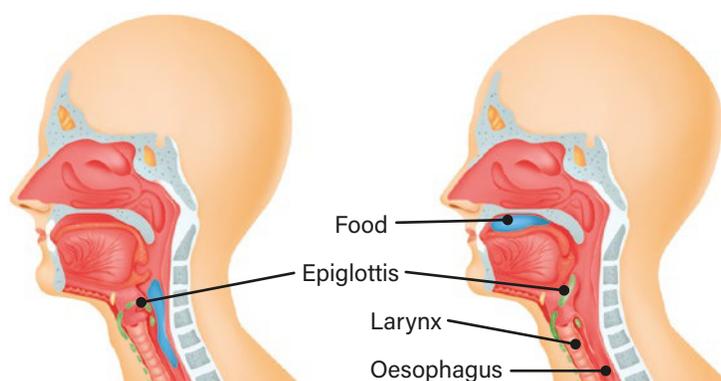
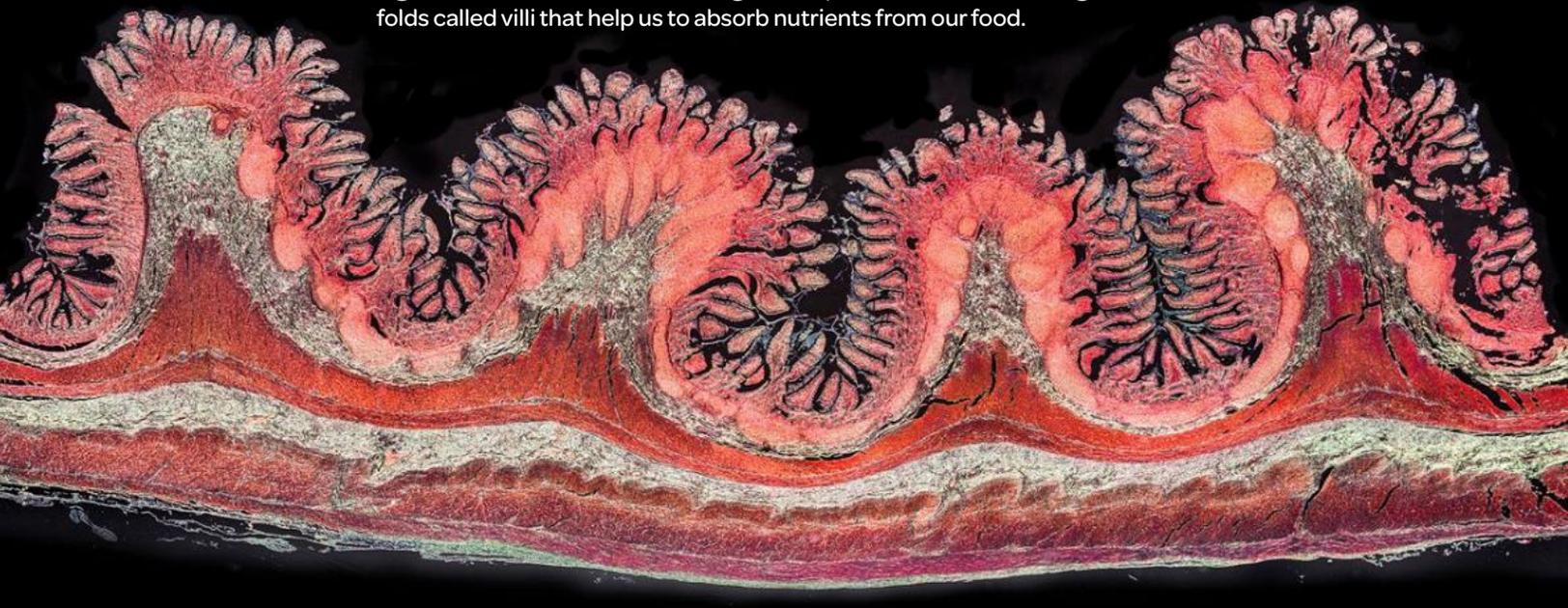


Figure 2.6: The epiglottis shifts to cover the trachea when we swallow so that food can pass into the oesophagus rather than block our airway.

Figure 2.7: The intestines of our digestive system contain lots of finger-like folds called villi that help us to absorb nutrients from our food.



Specialised cells in the digestive system help it carry out its functions

The small intestine is lined with tiny projections called **villi**. Villi have specialised cells that help absorb nutrients during digestion. Villi contain capillaries, which are the smallest types of blood vessels. These capillaries allow nutrient molecules to pass through and to be dispersed in the body where needed. The shape of the villi maximises the amount of nutrients that can be absorbed, because the finger-like projections increase the surface area of the small intestine wall (see Figure 2.7). The greater the surface area, the greater the opportunity for the chyme mixture to come into contact with the intestinal capillaries.

Reflux is a disorder of the digestive system

Reflux is a disorder of the digestive system that can result in a person feeling pain or a burning sensation in their upper abdomen or chest. The condition is caused by stomach acid leaking from the stomach and moving up into the oesophagus. Antacids are bases that neutralise or cancel out the acid, and help stop the symptoms of reflux (see Figure 2.9).

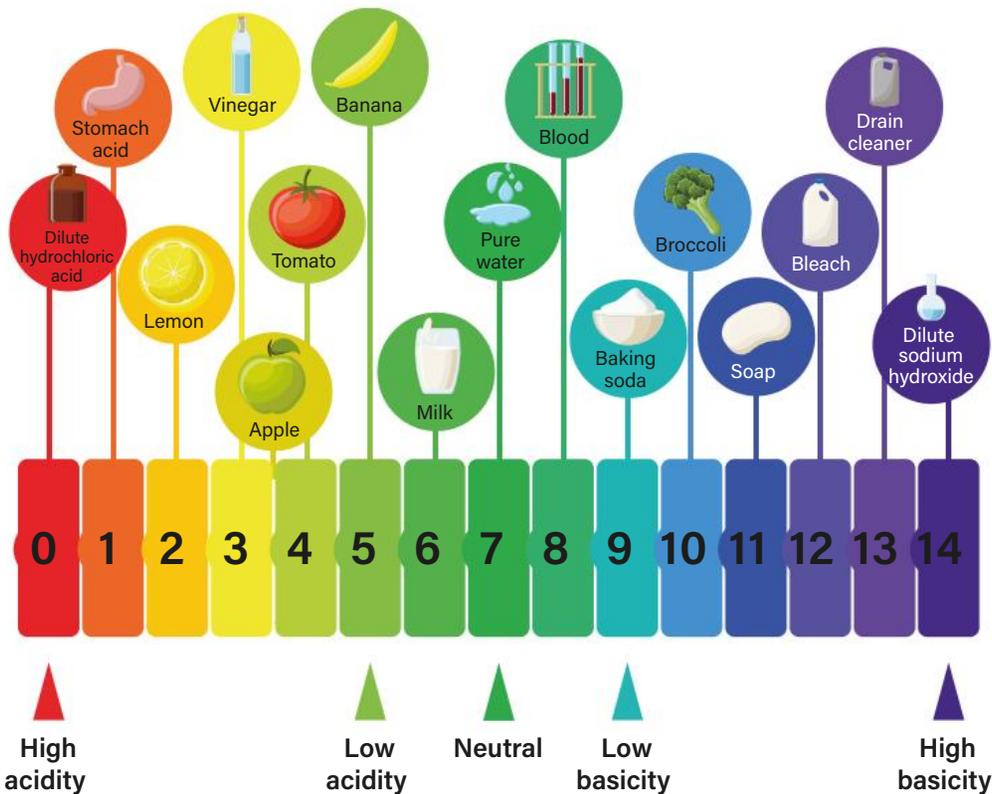


Figure 2.8: This pH scale shows the acidity and basicity of different foods and substances.

Figure 2.9: ▶

Antacids such as milk of magnesia can ease the symptoms of reflux by neutralising the acidic fluids in the oesophagus. Stomach acid has a pH of 1 and turns universal indicator red. Adding milk of magnesia causes the colour to change to green.



Learning Ladder

Systems of living things

- 1 a** State the purpose of the digestive system in one sentence.
b Identify the main organs that make up the digestive system.
- 2** Construct a step-by-step flowchart to describe the process of digestion, from the moment you take a bite of food to when you expel faeces.
- 3 a** Explain the difference between mechanical and chemical digestion.
b 'Bolus' refers to food that has been chewed and swallowed into the oesophagus. What are the similarities and differences between bolus and chyme?
- 4** Discuss how a person would be affected if their intestine walls were flat due to the absence of villi. Suggest how the person could modify their lifestyle to adjust to the lack of villi.

Use and influence of science

- 1** Which of the following suggestions related to people who are lactose intolerant does *not* create an ethical issue?
A Milk should be banned because many people are not able to digest lactose, which is commonly found in milk.
B Milk products and substitutes should be clearly labelled, whether they contain lactose or not.
C People who are lactose intolerant must wear white wristbands so that everyone can accommodate their needs.
- 2** Indigestion is characterised by stomach acid rising into the oesophagus. Scientific knowledge led to the development of antacid tablets, which ease the painful symptoms. Propose and describe how this development has affected society.
- 3** Explain your response to Question 1. Discuss the suggestion(s) that *could* create an ethical issue.

Questioning and predicting

p. 232

- 1** Which of the following is the *most* suitable question or statement for investigating a scientific concept?
A How long does it take people to digest a sandwich?
B Amylase enzymes in the saliva start to break down complex carbohydrates in the mouth.
C How does the amount of water you drink with a meal affect how long it takes to digest?
- 2** Lactase is the enzyme required to break down lactose in milk. Predict what would happen if a person were unable to produce lactase in their body.
- 3** Construct a scientific question to investigate how the surface area of digestive structures (such as villi) affects the rate of chemical reactions, using marble chips and hydrochloric acid to simulate the reaction.
- 4** Develop a hypothesis that predicts the outcome of the investigation question you constructed in Question 3. Use an 'If ..., then ...' statement to structure your hypothesis.
- 5** Evaluate your hypothesis from Question 4 to ensure the relationship between the independent and dependent variables is valid.

Key idea: Systems

Choose one digestive system organ: gallbladder, pancreas, appendix or spleen. Research how losing this organ or its function affects digestion. Share your findings with a classmate, and include interesting facts or real medical cases.

Success criteria

- I can identify the main organs that make up the digestive system.
- I can describe, using annotated diagrams, how the digestive system provides the body with nutrients.

2.3 ▶ The respiratory system

Learning intention

At the end of this lesson, I will be able to:

- identify the role of the human respiratory system and name the major organs in this system
- describe how the structures and specialised features and cells of the respiratory system enable it to carry out its functions.

Key terms

aerobic respiration: the process of turning glucose into energy where the cells take in oxygen and release carbon dioxide

cellular respiration: the process of turning glucose into energy for cells to use

diaphragm: the band of muscle under the lungs that enables the physical action of inhalation and exhalation

diffuse: to move from an area of high concentration to an area of low concentration

gas exchange: the exchange of oxygen and carbon dioxide between an organism and the environment

hiccups: when the diaphragm contracts involuntarily and repeatedly to produce a vocal 'hic' sound

Investigation 2.3

Breathing rate and exercise, p. 303

Key idea: Systems

The role of the human respiratory system is to bring oxygen into the body and remove waste gases.

The respiratory system is responsible for gas exchange

The major parts of the human respiratory system are the nose, mouth, trachea, bronchi and lungs. The lungs contain smaller, more specialised parts such as the bronchioles and alveoli (see Figure 2.10).

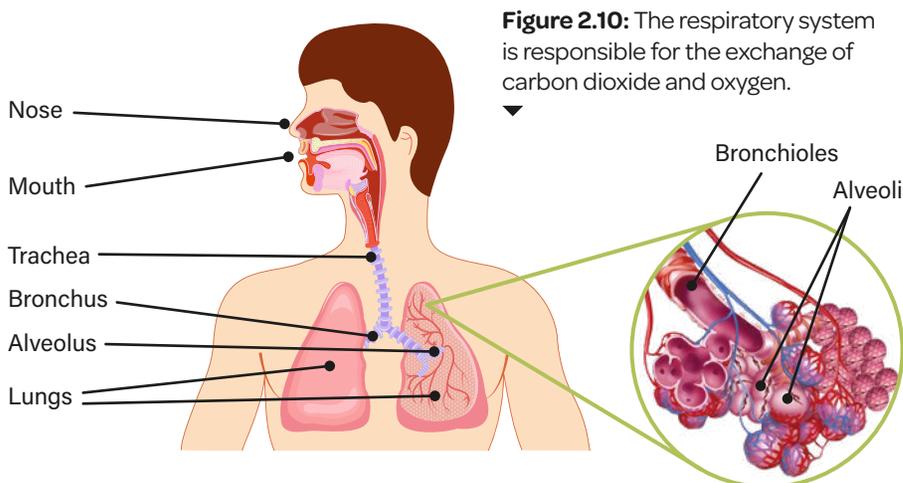


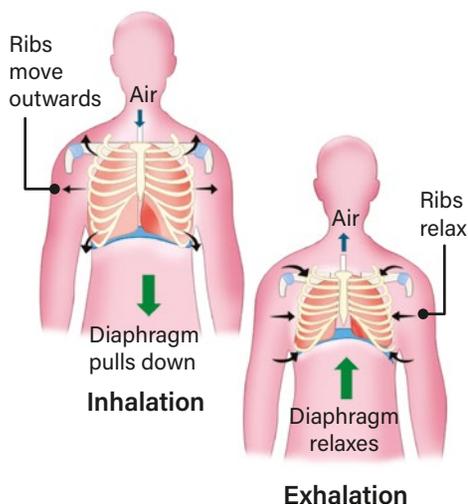
Figure 2.10: The respiratory system is responsible for the exchange of carbon dioxide and oxygen.

The human respiratory system gathers and processes oxygen. You breathe in (inhale) oxygen with air, and release carbon dioxide and water vapour when you breathe out (exhale). This **gas exchange** is only possible because of the special structures of the respiratory system.

During inhalation, air enters the nostrils or mouth and moves into the trachea (windpipe). It then travels into two branching bronchi – one for each lung – before passing into smaller and smaller passages called bronchioles. At the end of the bronchioles are clusters of tiny sacs called alveoli. Each alveolus is moist, thin and surrounded by many microscopic blood vessels called capillaries. Oxygen from the air **diffuses** through the thin cell membranes of the alveoli and into the capillaries. From there, it is transported by the blood to cells throughout the body for **aerobic respiration**.

At the same time, carbon dioxide and water that collect in the blood as products of **cellular respiration** are taken back to the lungs for removal. Carbon dioxide and water vapour diffuse back into the air within the alveoli. When you exhale, the air in the alveoli is swept back through the lungs, taking the reverse route to exit the respiratory system.

Figure 2.11: When the diaphragm contracts and relaxes, the chest expands and constricts.



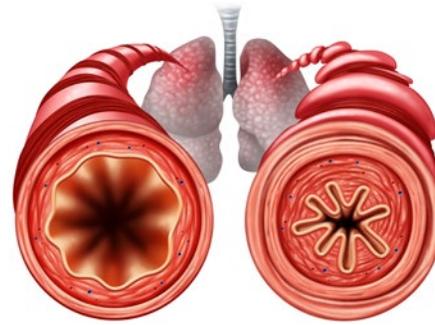
The diaphragm is a specialised part of the respiratory system

The **diaphragm**, a band of specialised muscular and connective tissue, separates the chest cavity from the abdomen cavity. It plays a crucial role in the respiratory system despite not being directly involved with gas exchange. As shown in Figure 2.11, when you inhale, your diaphragm contracts to move downwards. This causes your ribs to move outwards, which increases the space in your chest cavity. This creates suction in your airway, drawing air into your lungs from outside your body through your nose or mouth, trachea and bronchi. When your diaphragm relaxes, the opposite occurs. It returns to its upward position, pushing air out of the lungs, meaning you exhale.

When the diaphragm suddenly contracts without warning, it closes off the vocal cords, producing a 'hic' sound. When this occurs repeatedly over a relatively short amount of time, we call it the **hiccups**. While usually harmless, persistent hiccups could signal an underlying medical issue.

Asthma is a disorder of the respiratory system

Asthma occurs when a person's airways become inflamed and narrow, making it difficult to breathe.



◀ **Figure 2.12:** A healthy bronchial tube (left) and an unhealthy bronchial tube (right). This shows how the airway of a person with asthma can be restricted.

Symptoms of asthma include wheezing, coughing, tightness in the chest and shortness of breath. It is like trying to breathe through a thin straw. Many things can trigger an asthma flare-up, such as allergens, stress, illness or exercise. Medical treatment such as a quick-relief inhaler dilates the bronchi and eases the airway restriction.

Learning Ladder

Systems of living things

- 1 a** State the purpose of the respiratory system.
b Identify the main organs of the respiratory system.
- 2 a** Describe the role of alveoli in respiration.
b Propose an advantage of having thousands of tiny alveoli in the lungs.
- 3** Explain why carbon dioxide in blood needs to be exchanged with oxygen from the air.
- 4** A person is paralysed from the chest down but can move their head, neck and face. Discuss how this might affect the functioning of their respiratory system. Use as many key terms from this section as possible.
- 5** *Breathing and respiration are pretty much the same thing.* Do you agree? (Refer to the structure and function of the respiratory system.)

Nature and development of science

- 1** Identify a common way that science has addressed problems with asthma.
A Wait for people to grow out of it.
B Remove bronchial tubes.
C Prescribe use of a quick-relief inhaler.
- 2** Propose and describe how a pulmonary surgeon (lung doctor) and personal trainers might work together to rehabilitate a lung transplant patient.

Communicating

p. 255

- 1** Identify and define at least three scientific words from this section that are not in the list of key terms.
- 2** See Figure 2.10. Describe how the diagram has been annotated to show the small features of the bronchioles. Propose another way to communicate information about the parts of the lungs.
- 3** Prepare an annotated poster to teach a group of Year 7 students about the respiratory system. Include the main features, as well as each of their functions.
- 4** Convert your poster from Question 3 into a digital slide, using animations to convey information to your audience one feature and function at a time.

Key idea: Systems

Research the structures of the respiratory systems in other animals such as fish and amphibians. Construct a table to compare them with those of a mammal. To extend yourself, create an infographic to display your findings.

Success criteria

- I can identify the role of the human respiratory system and name its main organs.
- I can describe how the specialised features and cells of the respiratory system enable it to carry out its functions.

2.4 ▶ The circulatory system

Learning intention

At the end of this lesson, I will be able to:

- identify the role of the human circulatory system and name the major organs in this system
- describe how the structures and specialised cells of the circulatory system enable it to carry out its functions.

Key terms

aorta: the main artery that leads from the heart to the rest of the body

artery: a type of blood vessel that carries blood away from the heart

atria: filling chambers of the heart

blood vessel: a tube such as a vein or artery that carries blood in the body

capillary: the smallest type of blood vessel

cardiovascular: related to the heart (cardio) and blood vessels (vascular)

vein: a type of blood vessel that returns blood to the heart

vena cava (plural **venae cavae**): the main vein that leads to the heart from the rest of the body

ventricles: pumping chambers of the heart

Investigation 2.4

Dissecting a heart, p. 305

Key idea: Systems

You now know that the digestive and respiratory systems provide nutrients and oxygen for our bodies, which are required for survival.

However, it is the job of the circulatory system to make sure those things get to where they are needed.

The circulatory system includes an intricate highway of vessels that allow blood, the transport medium, to be continuously pumped throughout all parts of the body.

Figure 2.13: ▶ The circulatory system includes the heart, blood vessels and blood.

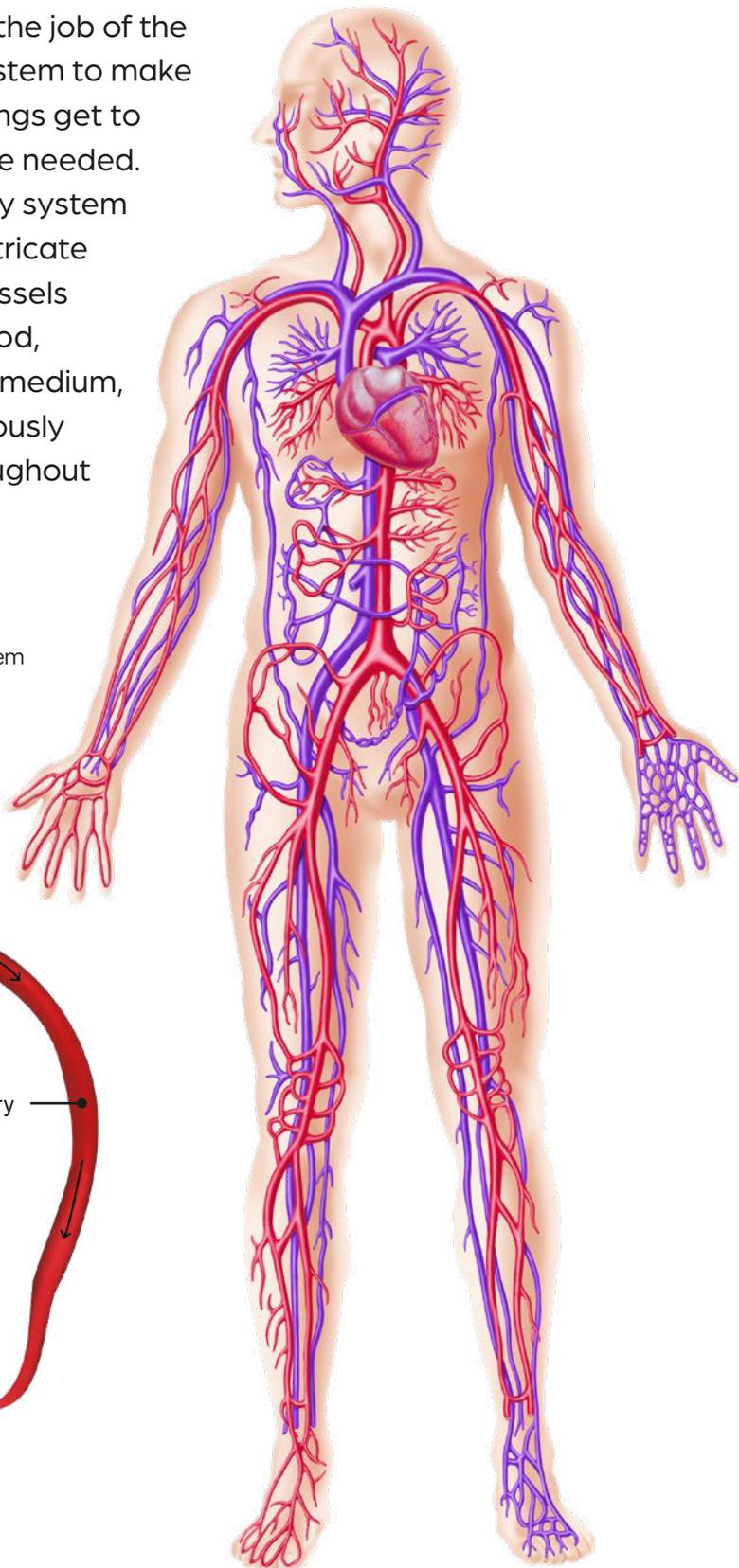
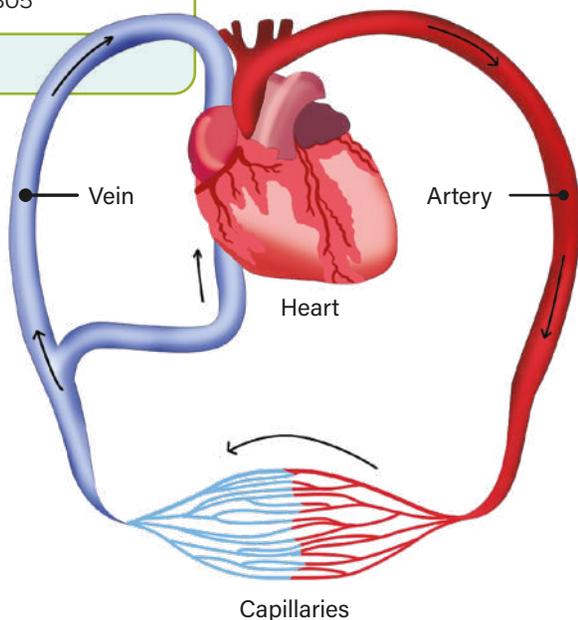


Figure 2.14: ▶ Arteries carry blood away from the heart and veins carry blood towards it.



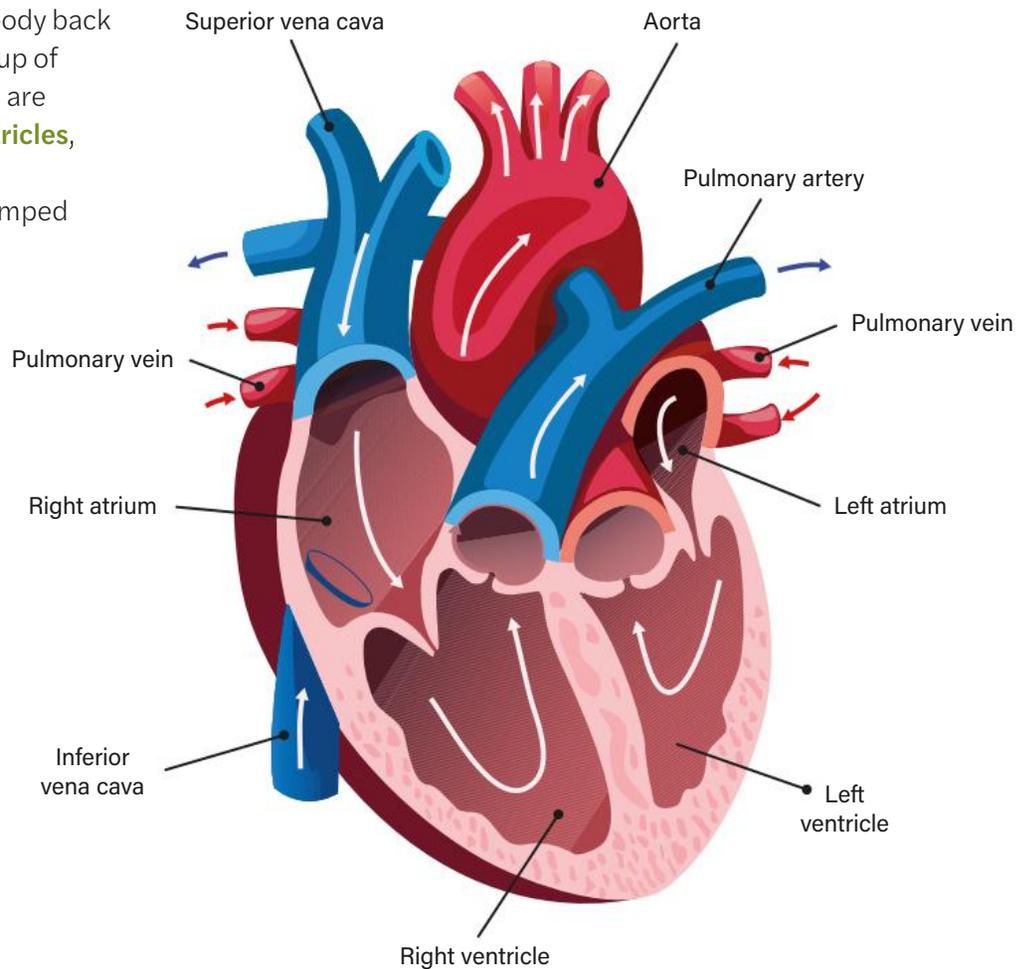
The circulatory system transports substances around the body

Your heart, blood vessels and blood make up your circulatory system. This system delivers oxygen, nutrients and other substances to every tissue in your body. It also helps your body to remove waste products, such as carbon dioxide.

The three main types of **blood vessels** are arteries, veins and capillaries (see Figure 2.14). **Arteries** take blood from the heart to the body. They have thick, muscular walls that expand and contract as the heart beats. **Veins** take blood from the body back to the heart. Their walls are not as thick as those of arteries, and they contain valves to keep the blood flowing in the right direction. **Capillaries** are the smallest blood vessels. They take blood to the body's cells. The walls of capillaries are one cell thick, which allows nutrients and oxygen to move easily into the cells from the blood, and waste products to move out of the cells into the blood.

The heart and blood vessels pump oxygenated blood from the lungs to the body's cells and deoxygenated blood from the body back to the lungs. The heart is made up of four chambers: two **atria**, which are 'filling' chambers; and two **ventricles**, which are 'pumping' chambers. Blood enters the atria and is pumped out through the ventricles (see Figure 2.15).

Figure 2.15: The heart pumps blood in specific directions through a complex series of vessels, chambers and valves. The blue vessels contain deoxygenated blood and the red vessels contain oxygen-rich blood.

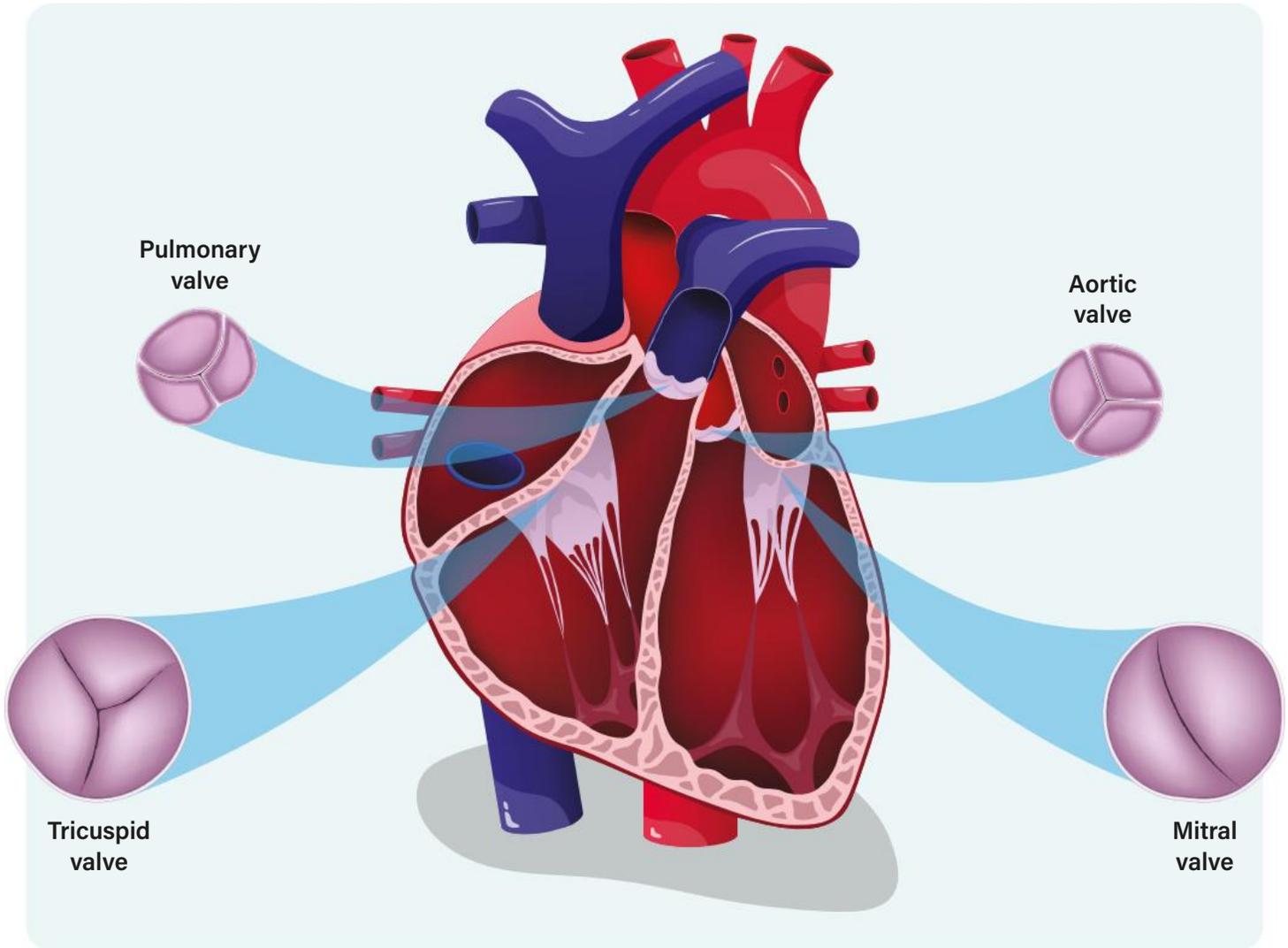


The process is as follows:

- 1 At the lungs, the blood picks up oxygen and flows through the pulmonary veins into the left atrium of the heart.
- 2 The oxygenated blood moves down into the left ventricle and is pumped out of the heart through the **aorta**, which is the main artery that leads to the rest of the body.
- 3 Once the blood has delivered oxygen to cells all over the body and collected waste material, it travels back to the heart.
- 4 The deoxygenated blood enters the right atrium of the heart from the superior (top) and inferior (bottom) **venae cavae**, which are the main veins that lead to the heart from the rest of the body.
- 5 The blood then flows down into the right ventricle, before being pumped back to the lungs for gas exchange via the pulmonary artery.

This is a cyclical process, so there is no start or finish.

▼ **Figure 2.16:** Specialised valves in the heart are vital in supporting the overall function of the circulatory system.



Heart valves are specialised parts of the circulatory system

The heart is the hardest working muscle in the body, with an adult's heart beating more than 115 000 times a day. **Cardiovascular** health is reliant on the heart's valves and tendons working efficiently. Heart valves allow blood to flow in one direction during the heartbeat cycle. They are highly organised connective tissue structures, consisting of several types of specialised cells.

The mitral valve, also called the bicuspid valve, regulates flow from the left atrium into the left ventricle. The aortic valve opens through to the aorta. When deoxygenated blood returns to the right atrium, the tricuspid valve lets it through to the right ventricle. Finally, the pulmonary valve promotes blood flow back to the lungs to be reoxygenated.

The mitral and tricuspid valves are assisted by a series of tough yet flexible tendons called chordae tendineae, commonly known as 'heartstrings'. If these valves or tendons are damaged or malfunctioning, this can cause serious conditions such as a heart murmur, valve stenosis or mitral regurgitation, each of which can lead to heart failure.

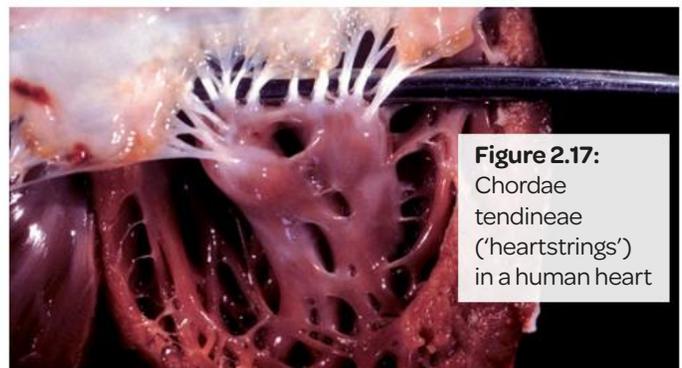


Figure 2.17: Chordae tendineae ('heartstrings') in a human heart

Heart disease can be caused by many factors

In addition to the valve disorders mentioned above, there are many other conditions that can lead to cardiovascular disease. The most common conditions are:

- high blood pressure: when the force of blood pushing against arteries is too high
- high cholesterol: which contributes to narrowing (clogged) arteries, which restricts blood flow.

Diets high in salt and saturated fats, smoking or vaping, and being generally inactive are things that lead to high blood pressure and high cholesterol. Cases range from mild to severe. If these conditions are left untreated, they usually get worse and lead to complications such as heart attacks or stroke.



Figure 2.18: There is a clear relationship between poor lifestyle choices and heart disease.

The good news is that reducing your risk of developing heart disease is within your control. So, to ensure that your circulatory system is in tip-top shape, maintain a healthy lifestyle, including eating a balanced diet and taking regular physical exercise.

Learning Ladder

Systems of living things

- 1 Identify the differences between a vein and an artery.
- 2 Describe how the heart and blood vessels work together to keep the body oxygenated.
- 3 Construct a diagram of the circulatory system.
 - a Annotate the diagram to describe the parts of the circulatory system and their functions.
 - b Label the directional flow of blood throughout all structures in your diagram, including whether the blood is oxygenated or not.
- 4 Discuss the importance of heart valves and heartstrings to the overall function of the circulatory system, including what could happen if they are damaged.
- 5
 - a Identify the advantage of having separate right and left chambers of the heart.
 - b Suggest what problems would arise if they were not separated.

Use and influence of science

- 1 Identify whether cardiovascular disease is an economic, social or environmental issue. Provide a reason.
- 2 Propose how scientific knowledge about the connection between nutrition and heart health has affected society.
- 3 Some very tasty foods like ice cream and hot chips can be harmful to the circulatory system. Propose and explain an ethical impact related to scientific advances in the food industry.

Questioning and predicting

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- 1 Identify which of the following is the most suitable question to investigate scientifically.
 - A How many litres of blood can the heart pump in a day?
 - B How does fitness level affect the time it takes for heart rate to return to normal after 10 minutes of high-intensity exercise?
 - C How many times does a person's heart beat in a day?
- 2 Predict the effect of a blockage of a major artery as a result of high cholesterol. In your answer, refer to the purpose of the circulatory system.
- 3 Construct a scientific question to investigate the resting heart rates of humans, cats, sheep and horses.

Key idea: Systems

Propose which part of the circulatory system is the most important. Write an evidence-based argument to convince your audience to agree with your perspective. Use as much new scientific terminology as you can.

Success criteria

- I can identify the major structures of the heart and differentiate between the main types of blood vessels.
- I can describe, using annotated drawings, how the circulatory system transports and delivers oxygen to all parts of the body.

2.5 ▶ The excretory system

Learning intention

At the end of this lesson, I will be able to:

- identify the role of the human excretory system and name the major organs in this system
- describe how the structures and specialised cells of the excretory system enable it to carry out its functions.

Key terms

excretion: the elimination of cellular waste from the body through urine

glomerulus: a bundle of capillaries; the filtering unit within each nephron

nephron: a microscopic filtration structure in the kidneys that removes waste and excess water

renal: an adjective that means 'related to the kidney'

tubule: a small tube made of epithelial cells

urea: a product of the chemical breakdown of food, specifically proteins

Key idea: Systems

The processes occurring in our bodies produce wastes. If they are not removed, wastes can build up and cause harm. The body removes some forms of waste by exhaling or through sweat and faeces. **Excretion** refers mainly to the elimination of cell waste from the body through urine.

The excretory system removes waste from the body

Many specialised organs are involved in excretion, or the removal of waste, including the skin, lungs and liver. Specific organs also produce and eliminate urine. Four main organs make up the excretory system:

- **Kidneys** filter waste from the blood in the form of urine.
- **Ureters** carry urine from the kidneys to the bladder.
- The **bladder** is a muscular reservoir that stores urine.
- The **urethra** carries urine from the bladder out of the body.

The kidneys are two bean-shaped organs at the back and upper portion of the abdomen. The kidneys filter harmful wastes from the blood and ensure that the body retains the right amount of water. One major waste product is **urea**, a type of nitrogenous (containing nitrogen) waste produced in the liver. Urea is a by-product of reactions that break down proteins, which are large food molecules that contain nitrogen. Urine contains urea and any other substances that have been removed from the blood. Urine leaves the kidneys through the ureters and is stored in the bladder until it is expelled through the urethra. The blood that has been filtered then returns to the circulatory system through the **renal** vein.

Nephrons are structures within the kidneys

When blood moves into the kidneys through the renal arteries, it meets several pyramid-shaped structures made up of microscopic nephrons. **Nephrons** are filtration **tubules** that remove waste products and excess water. Each kidney contains about a million nephrons.

A nephron is made up of several types of highly specialised cells. Each type carries out a specific part of the filtration process. The main filtering unit within the nephron is a bundle of capillaries called the **glomerulus**, enclosed in a sac called the Bowman's capsule. From there, a network of tubular structures absorb and reabsorb components of the clean blood, ensuring that substances the body needs, such as glucose, remain in the blood. Collecting ducts from each nephron combine the waste to form urine (see Figure 2.20).

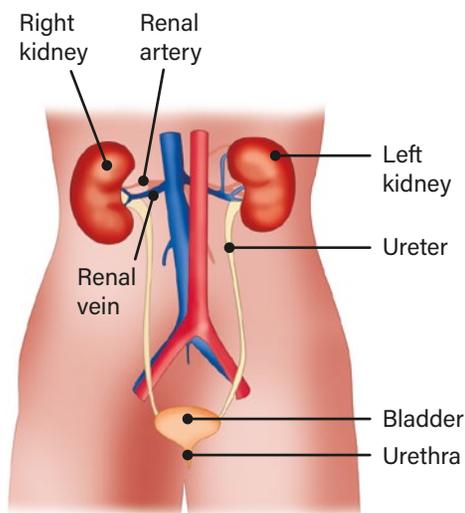


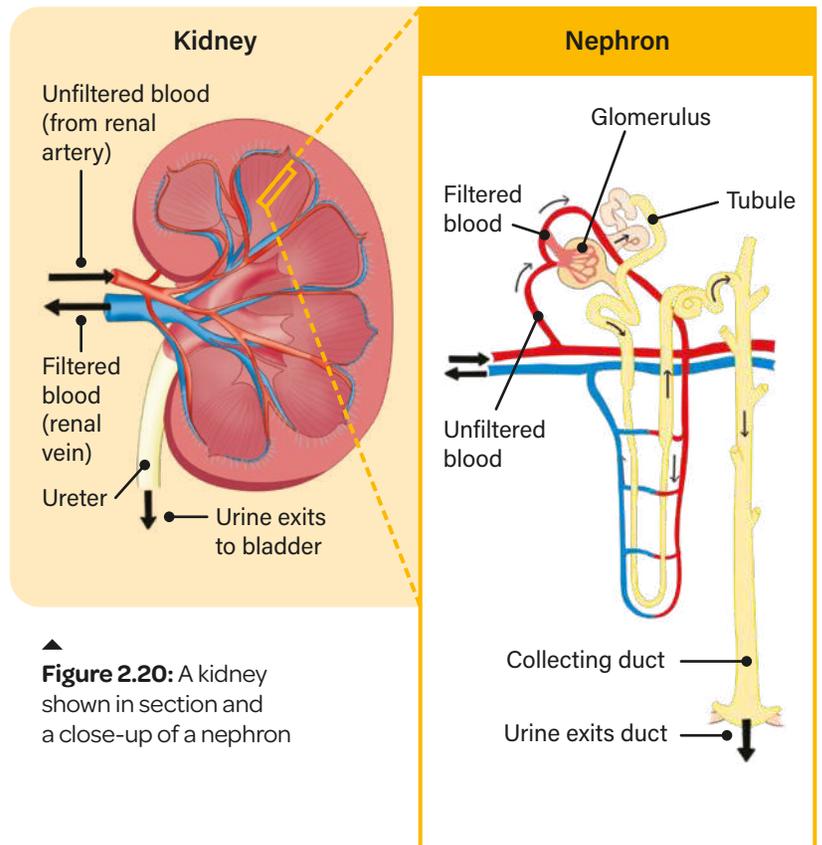
Figure 2.19: The excretory system is made up of the kidneys, ureters, bladder and urethra.

Kidney disease is a disorder of the excretory system

Renal disease is any disorder of the kidneys. If the kidneys do not work properly, toxins build up in the body, causing harm.

Kidney stones are like tiny rocks that form in the kidney, made up of minerals and salts from the urine. Usually, they are passed through urination, but large stones can get stuck and cause problems. They can be very painful and block urine flow, which can cause infection and lead to renal failure. It is possible to break the stones into smaller pieces so they can be passed into the ureter. Otherwise, they can be removed surgically. To avoid kidney stones, it is important to drink plenty of water and eat a healthy diet.

If the kidneys fail, the blood can be cleaned by dialysis, a process that mimics filtration by the nephrons. Eventually, though, it may be necessary to have a kidney transplant.



Learning Ladder

Systems of living things

- Recall the specialised organs that are involved in the elimination of urine from the body.
- Describe the role of the kidneys, ureters, bladder and urethra in removing waste from the body.
- Explain how the excretory system ensures the human body can function effectively.
- People can live a normal life with only one kidney.
 - Outline how this is possible.
 - Propose some things you might recommend to someone with only one kidney.
- Defecation is the process of expelling faeces from the rectum. Evaluate the following statement: *Defecation is a type of excretion because it removes food waste from the digestive system.* Do you agree with the statement? Explain your answer.

Nature and development of science

- Identify a kidney problem that can arise from not drinking enough water.
- Propose how a nutritionist can complement advice from your renal doctor about managing a kidney disorder.

Communicating

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- Construct a glossary of terms and definitions for all the scientific words used in this section.
- Refer to Figure 2.19.
 - Describe the features that enable the figure to communicate the main organs of the excretory system.
 - Propose how a labelled diagram can be enhanced or modified to show the functions of each part of the excretory system.
- Prepare a flowchart to outline how blood is filtered through the excretory system to produce and eliminate urine.

Key idea: Systems

Urinary tract infections can impact the excretory system. Investigate the causes and symptoms of, and treatments for, urinary tract infections. Explain how these infections can be prevented.

Success criteria

- I can identify the main organs of the excretory system.
- I can use annotated drawings to describe how the excretory system rids the body of waste.
- I can explain how disorders of the kidneys can affect the overall functioning of the excretory system.

2.6 ▶ Body systems in action

Learning intention

At the end of this lesson, I will be able to explain the importance of systems in multicellular organisms working together to enable survival by providing cell requirements, including gases, nutrients and water, and removing cell wastes.

Key term

hormone: a chemical substance produced by the body that controls the activity of certain cells or organs

Key idea: Systems

Body systems exist in almost every multicellular organism. These specialised organ systems each have a specific purpose. For an organism to survive, each system must work with the others, often passing materials from one system to the next.

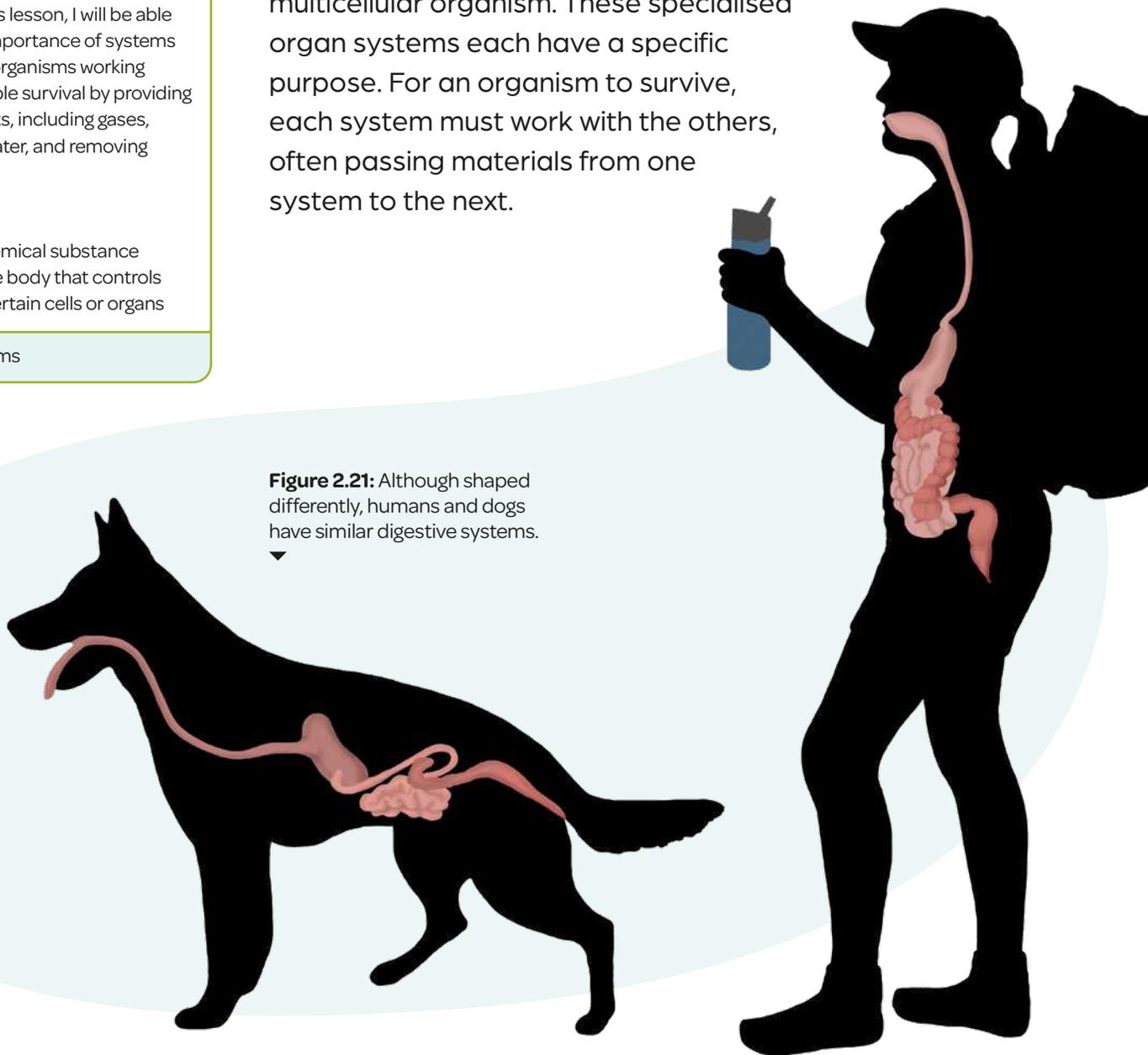


Figure 2.21: Although shaped differently, humans and dogs have similar digestive systems.

Animals have several body systems

Multicellular organisms are incredibly diverse, so the number and type of body systems can differ between organisms. We have discussed four of them in detail, but most animals, such as humans, have 11 major body systems (see Table 2.2).

Some of these systems can be identified in other ways. For example, the body's skeleton and muscles can be considered separately, as the skeletal and muscular systems, or together, as the musculoskeletal system.

Table 2.2: The 11 major body systems

Body system	Function
Circulatory	Transports important materials such as oxygen and nutrients in blood through a vast network of blood vessels. Arteries carry blood away from the heart and veins carry blood towards the heart.
Nervous	Detects, processes and sends electrical signals
Respiratory	The oxygen in the lungs is moved into the blood and delivered to the cells for respiration. The carbon dioxide produced by cells is taken to the lungs to be removed.
Digestive	Breaks down food into nutrients, which are absorbed into the blood and transported to the cells
Skeletal	Provides support and structure to the body and organs
Muscular	Allows movement through the use of muscles
Excretory	Waste products from cellular processes move from cells into the blood, to be removed by the organs of the excretory system
Endocrine	Produces hormones , which control growth and development
Reproductive	Produces sex cells, and supports pregnancy and birth
Immune	Makes white blood cells, which fight diseases and infections
Integumentary	Protects the body from damage

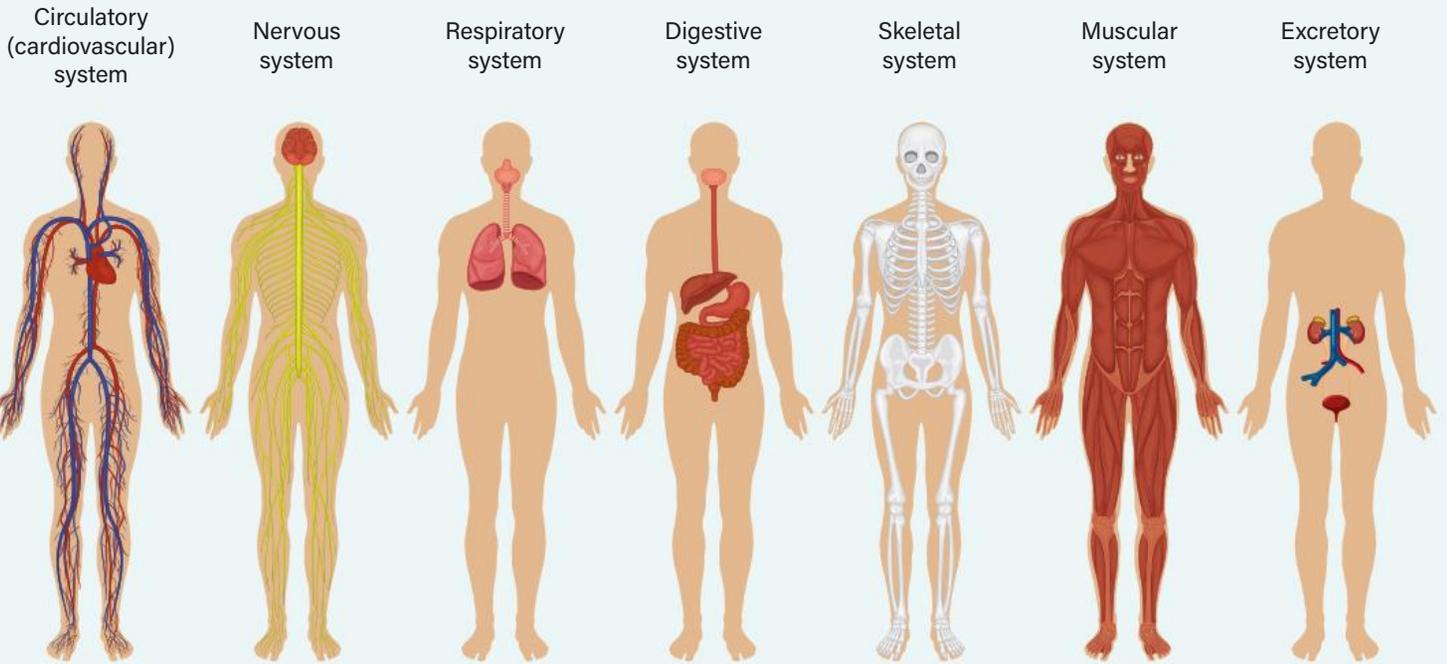


Figure 2.22: The human body is made up of different systems that work together to provide cells with everything they need to survive.

▼ **Figure 2.23:** The body's organ systems are all interlinked.

Circulatory system

Important materials like oxygen and nutrients are transported in blood through a vast network of blood vessels in the body's circulatory system. Arteries carry blood away from the heart and veins carry blood towards the heart.



Respiratory system

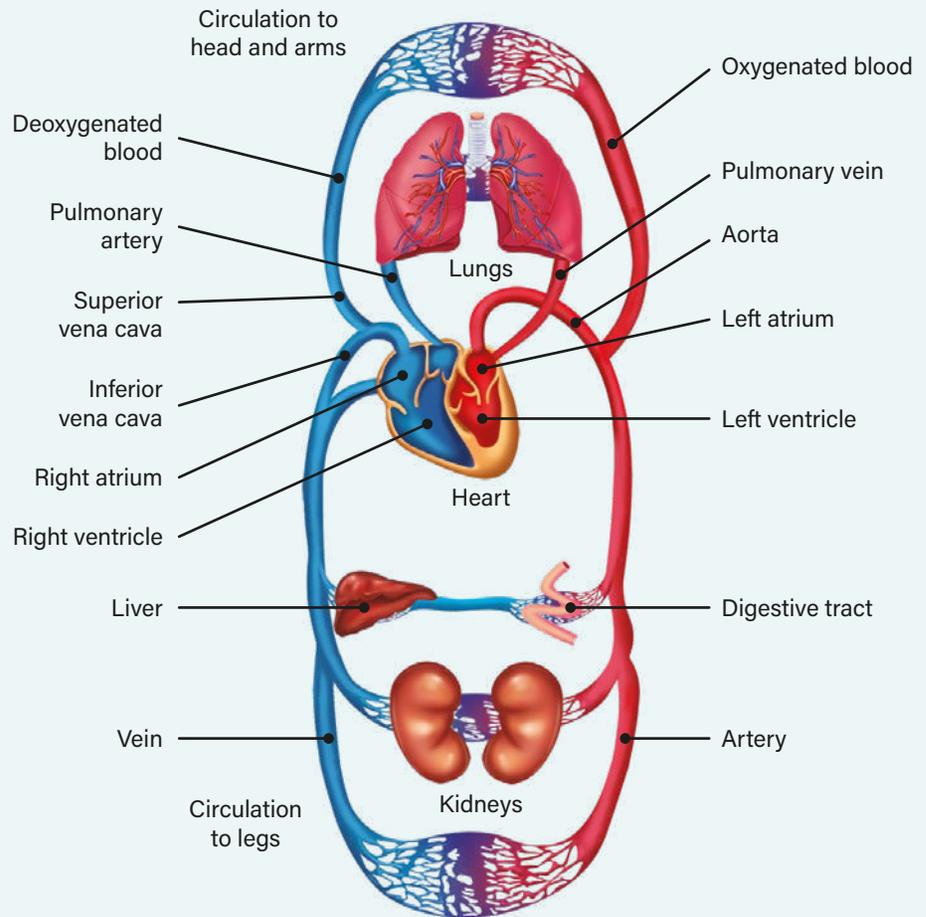
Oxygen and carbon dioxide are exchanged between the lungs and blood. The oxygen in the lungs is moved into the blood and delivered to the cells for respiration. The carbon dioxide produced by cells is taken to the lungs to be removed.



Body systems work together to meet cell needs

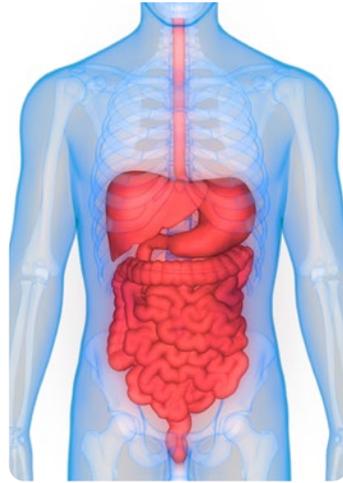
Body systems must work together to provide cells with everything they need to function and survive, such as gases, nutrients and water. One of the best examples of this is in the human body. The human circulatory system is connected to every other system in the body. It transports nutrients, dissolved gases and waste products between cells (see Figures 2.23 and 2.24). Without the circulatory system, other systems would not be able to function.

▼ **Figure 2.24:** The circulatory system is linked to all other body systems.



Digestive system

Food is broken down into nutrients by the digestive system. These nutrients are absorbed into the blood, where they are transported to the cells that need them.



Excretory system

Waste products produced from cellular processes move from the cells into the surrounding blood, to be removed by the organs of the excretory system.



Learning Ladder

Systems of living things

- 1 Identify the system that assists with removal of wastes in the body.
- 2 Identify and describe one feature of at least two body systems that allows them to interact.
- 3 **a** Explain how the musculoskeletal system provides structure for at least two other body systems.
b Discuss how the two body systems you identified in part a would be affected if there were no skeletal system.
- 4 Both the circulatory and respiratory systems are responsible for ensuring that oxygen gets to our cells. Compare how they are responsible.
- 5 Cells require oxygen and water to survive. Discuss which body systems may assist cells to obtain these materials.

Use and influence of science

- 1 True or false?
Air pollution is an example of an environmental issue that can impact people's respiratory system.
- 2 Describe why environmental protection authorities may have to collaborate with respiratory doctors to come up with guidelines for industries that cause pollution.
- 3 Explain the ethical impacts of using laboratory animals with human-like body systems to make scientific advances related to the human body.
- 4 Ethics approval requirements can make it challenging to study animals in the laboratory. Discuss how this impacts scientific developments.

Communicating

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- 1 Identify why 'body system' means the same as 'organ system' in the human context.
- 2 Describe why each body system is represented on a separate diagram of the human figure, rather than having all body systems shown on a single diagram.
- 3 Create a cyclical flowchart that shows the interconnectedness between the body systems shown in Figure 2.22.
- 4 Choose at least four body systems and create a digital table that distinguishes their cells, organs, functions and primary purpose.
- 5 Annotate your flowchart from Question 3 with scientific drawings and information suitable for a Year 5 audience. Highlight the interconnectedness of the body systems that enable survival of organisms.

Key idea: Systems

Compare a human body system with the body system of a different animal. Display your findings using visual creativity – for example, a flowchart with annotated images.

Success criteria

- I can identify components of body systems that interact between systems.
- I can explain how body systems work together to enable an animal to function efficiently.

2.7 ▶ Plant systems in action

Learning intention

At the end of this lesson, I will be able to describe the role, structure and function of the components of a plant system in maintaining its survival.

Key terms

epidermis: the outer layer of cells

phloem: a tubular structure that transports food around a plant

photosynthesis: the chemical reaction, powered by sunlight, in plants that converts carbon dioxide and water into sugar and oxygen

respiration: a chemical reaction that converts glucose to energy

vascular tissue: tissue that transports fluid and nutrients throughout a plant

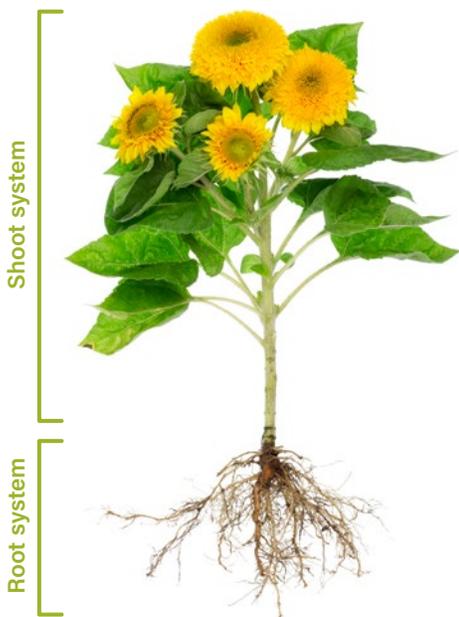
xylem: a tubular structure that transports water and nutrients from the roots to various parts of a plant

Investigation 2.7

Water transport in plants, p. 307

Key idea: Systems

Figure 2.25: Plants have two organ systems: the root system and the shoot system.



Like other multicellular organisms, plants also have organs and tissues. They carry out the vital functions of a plant, such as **photosynthesis** and the transport of water and nutrients.

Plants have four types of organs

Plants only have four different types of organs, as shown in Table 2.3. These organs are simple, but some carry out multiple functions.

Table 2.3: Plant organs and their functions

Organ	Functions
Roots	<ul style="list-style-type: none"> Absorb water and minerals from the soil; plants need water for photosynthesis and to dissolve and move substances around Anchor plant in the ground so that it does not fall over in strong winds or in ocean currents
Stem	<ul style="list-style-type: none"> Forms the main body of the plant (the trunk of a tree is the same as the stem of a rose) Provides support: helps a plant to stand up and bear the weight of leaves, flowers and fruit Transports nutrients: connects the root and shoot systems Aids growth: buds grow from the stem and form new branches, leaves or flowers
Leaves	<ul style="list-style-type: none"> Where photosynthesis takes place Sunlight is absorbed through the surface of the leaves, and products such as oxygen are released, or re-used during respiration.
Reproductive organs	<ul style="list-style-type: none"> To produce offspring Examples include flowers, fruits and seeds

Plants have a small number of tissue and organ systems

Plants have two organ systems: the root system and the shoot system (see Figure 2.25).

The **root system** consists of all the organs underground, such as the roots and any underground reproductive organs of the stem. This system absorbs nutrients and water from the soil. Despite it being called a root vegetable, when you eat a potato, you are eating part of the stem; it grows underground as part of the root system.

The **shoot system** mostly consists of the organs that grow above ground. These parts of the plant absorb sunlight and serve as the site for photosynthesis. The stem, fruit, flowers and leaves generally form the shoot system.

Plants also have four tissue systems made up of specialised cells that perform important functions but do not combine to form organs.

- The **epidermis** is like the skin of the plant. These tissue cells form the outer surface of the leaves and the plant body.
- **Vascular tissue** transports fluids and nutrients through the plant, much like blood vessels do in your body.
- **Ground tissue** is made up of the cells that produce nutrients during photosynthesis and store them for later.
- **Meristematic cells** develop into various organs of a plant and are responsible for growth.

Plants have two primary vascular tissues

The xylem and phloem are complex tissues that form tubular structures to transport water, nutrients and food throughout a plant. The **xylem** only allows a flow of water and dissolved nutrients in one direction, from the roots to the shoot system. The **phloem** allows a two-way flow of sugars, proteins and other organic substances. The xylem and phloem are located next to each other as a cluster of vessels that make up the vascular bundle (see Figure 2.26).

Vascular bundles can be arranged in different ways, depending on the plant and its functions.

Figure 2.26: Xylem and phloem make up vascular bundles.

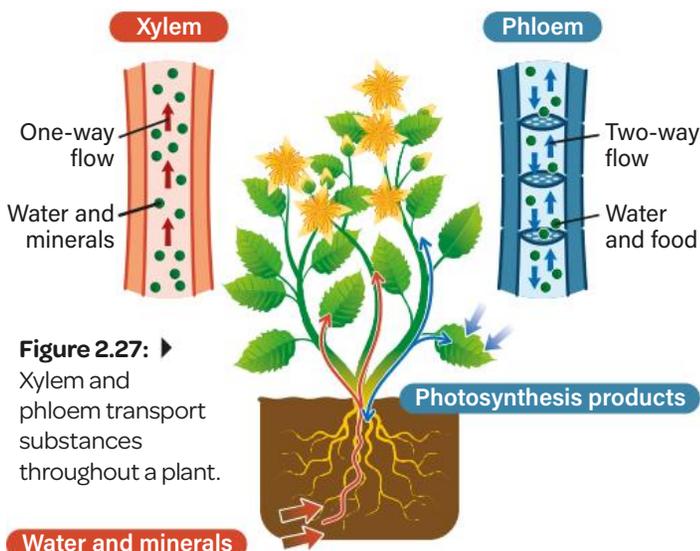
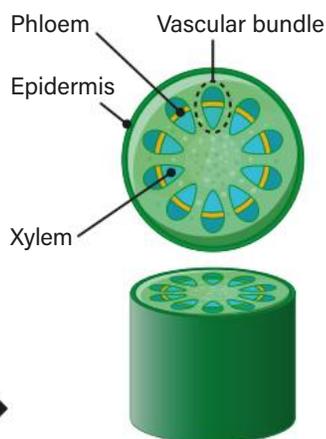


Figure 2.27: Xylem and phloem transport substances throughout a plant.

Learning Ladder

Systems of living things

- 1 Identify:
 - a the organs plants have.
 - b the organ systems plants have.
 - c the tissues of the transport system in plants.
- 2 Describe the functions of two important plant organs.
- 3 Explain the structure and function of each of the two organ systems in plants.
- 4 Discuss how a plant would be affected if either of its vascular tissues were damaged.
- 5
 - a Compare and contrast the role and functions of the xylem and phloem.
 - b Analyse the relationship between the structures and functions of the xylem and phloem.

Nature and development of science

- 1 Periods of drought can cause soil to become dry. Propose a problem that this creates for plants.
- 2 Plant systems and body systems have similarities and differences. Propose why botanists (plant scientists) and medical doctors might work together to learn about how long an organism can live without water.

Questioning and predicting

p. 232

- 1 Identify which of the following is the most suitable question to investigate a scientific concept.
 - A Will flowers die if you do not give them water?
 - B How does the length of its stem affect how long a flower survives in a vase with water?
 - C How long will a cut flower live without water?
- 2 Predict what will happen to a plant after a few days when you cut its stem to put it in a vase of water.
- 3 Construct a scientific question to investigate the variety of vascular bundle patterns in different plants.
- 4 Read Investigation 2.7 on page 307. Develop a hypothesis that predicts what will be observed.

Key idea: Systems

Conduct an online search to compare the vascular arrangement or patterns of the xylem and phloem of at least three types of plants. Display your findings in annotated diagrams. Try to link the patterns to the type or purpose of each selected plant system.

Success criteria

- I can identify the components of a plant system, including the xylem and phloem.
- I can explain how plant cells, tissues and organs work together to enable survival.

2.8 ▶ Flowering plants



Figure 2.28:
The main purpose of flowers is for reproduction.

Learning intention

At the end of this lesson, I will be able to explain the role of the flower and leaf in maintaining flowering plants as functioning organisms.

Key terms

chlorophyll: the green pigment in plant cells that absorbs sunlight and enables photosynthesis

pistil: the female reproductive part of a flower (the stigma, style and ovary)

pollen: the fine powder produced by the male part of a flower; contains male sex cells

pollination: the movement of pollen from the male part of a flower to the female part (from the anther to the stigma)

stamen: the male reproductive part of a flower (the anther and filament)

stomata: pores on the surface of a leaf; the site of gas exchange in plants

Investigation 2.8

Dissecting a flower, p. 308

Key idea: Systems

Flowers may look and smell beautiful, but their main purpose is to support plant survival through reproduction. Reproduction and photosynthesis both rely on specialised parts that work together to perform vital functions.

Flowers contain reproductive organs

Many flowers contain both male and female reproductive parts. The male reproductive part is called the **stamen** (see Figure 2.29). Each stamen is made up of the:

- **anther:** the organ that produces **pollen**, a fine powdery substance that contains the male sex cells of the plant
- **filament:** the stalk tissue that supports the anther.

The female reproductive part of a flower is called the **pistil** (see Figure 2.29). Each pistil is made up of the:

- **stigma:** the organ where pollen germinates
- **ovary:** the organ that stores the female sex cells (ova or eggs)
- **style:** the stalk tissue that connects the stigma and ovary.

Parts of a flower

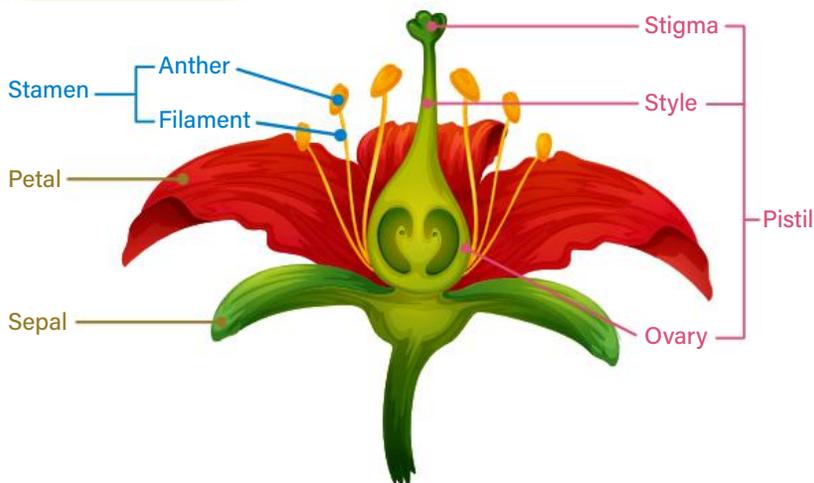


Figure 2.29: Flowers contain reproductive organs. The pistil is the female reproductive part and the stamen is the male reproductive part.

For plants to reproduce, pollen needs to be moved from the anthers to the female part of the flower to fertilise the ovum (egg). This is called **pollination**.

Pollination can be assisted by wind, rain, birds and insects such as bees. Birds and insects are attracted to bright and colourful flowers that smell nice and contain sugary nectar to eat.

Once fertilised, the ova (eggs) become seeds and the ovary swells and enlarges to become a fruit. The seeds in fruit can grow into new plants when conditions are suitable.

Photosynthesis happens in leaves

Leaves could be called the solar panels of plants because their main role is to perform photosynthesis, which produces energy for the plant's survival. Leaves have many features that make them perfect for carrying out this process. They are often flat, which increases their surface area, allowing them to absorb more sunlight. They are thin, so carbon dioxide can travel easily into the cells from the environment. Plants contain green pigments called **chlorophyll**, which absorb light energy from the Sun to produce food. Veins in plants allow water and other substances needed for photosynthesis to travel to the leaf cells.

If you look at a leaf under a microscope, you will see round pores called **stomata** (see Figure 2.30). Stomata open and close to allow the exchange of gases, such as oxygen and carbon dioxide, with their environment. Water can also pass through these pores, and water loss is sometimes an unwanted consequence of gas exchange.



Figure 2.30: Stomata are tiny pores on the surface of leaves that allow plants to exchange gases with their environment.



Figure 2.31: Plants need pollinators such as birds in order to reproduce.

Learning Ladder

Systems of living things

- 1 Identify the parts of the plant that make up the:
a stamen. b pistil.
- 2 Outline the process of photosynthesis.
- 3 Photosynthesis needs carbon dioxide, water and sunlight. Explain how chlorophyll compares to stomata in helping a plant to obtain these resources.

Nature and development of science

- 1 Plants consume carbon dioxide and release oxygen. Propose why planting trees is a solution to offset increased levels of carbon dioxide in the atmosphere.
- 2 Suggest three types of scientists who might work together to learn about how plant systems reproduce in a variety of environments and climates.
- 3 Explain how evidence about a new species of insect could lead to a scientific prediction about a 'yet-to-be discovered' species of flower.
- 4 Propose and discuss how microscopes have contributed to models of flowering plants.
- 5 Research two botanists from different parts of the world. Analyse if, or how, their perspectives aligned, and how this may have affected their scientific knowledge of flowering plants.

Communicating

p. 255

- 1 Classify the following features of a plant as either male or female: anther, filament, ovary, pistil, pollen, stamen, stigma, style.
- 2 Select a format to communicate the features of a flowering plant classified in Question 1.
- 3 a Create a digital diagram of a flower, similar to Figure 2.29.
b Label and describe its parts.
- 4 Construct an annotated flowchart showing the sequence of steps when plants reproduce.

Key idea: Systems

Roots grow underground and so do not get sunlight for photosynthesis.

- a Explain how root systems support photosynthesis.
- b Predict what could happen if erosion exposed roots.

Success criteria

- I can describe the main roles of the flower and leaf in the living system of a flowering plant.
- I can construct a diagram of a flowering plant to represent its main features and functions.

2.9 ▶ Key idea: Systems – when body systems fail

Learning intention

At the end of this lesson, I will be able to describe how advances in technology, combined with scientific understanding of the functioning of body systems, has enabled organ replacement and repair.

Key terms

ethical: relating to principles about what people think is 'wrong' and 'right'

Nobel Prizes: world-famous awards given each year for academic, cultural and scientific advances

Key idea: Systems

Organ transplantation allows organs, such as the heart, kidneys and lungs, to be given to someone who needs an organ because theirs is no longer working effectively as part of a particular body system. The biggest medical challenge in organ donation is an organ being rejected after someone receives it. Developments in technology mean that transplants are now more successful in allowing donated organs to function properly as part of the organ system in the body.

Figure 2.32: Instead of freezing organs, ▶ the TransMedics Organ Care System copies the conditions within the human body to replicate its function and keep the organ alive.



Figure 2.33: Cold storage may not be the most effective way to keep organs intended for transplant fresh and healthy. ▼



Technology has improved organ transplant medicine

For hundreds of years, attempts were made to transplant organs from one person to another, but they were not very successful. As doctors and scientists learnt more about body systems, organ transplants became more successful.

One problem for organ transplants is keeping the organs fresh and healthy after being removed from the donor. Currently, organs are kept in cold storage during transfer, but this can be harmful to the organ. In recent medical technology, scientists have made an artificial system that copies the conditions inside the human body, keeping organs fresh and capable of 'surviving' as they are moved from the donor to the recipient.

The human body tries to reject transplanted organs

As with any surgery, things can go wrong during organ transplants. The main cause of problems during transplants is actually the human immune system. The human body is always on the lookout for things that should not be there – this is how our immune systems protect us. Unfortunately, these things include cells from something that would be helpful – in this case, a donor organ.

To avoid this, doctors try to find a very close match between donor and recipient. Also, they use anti-rejection medication, which tries to stop the body from attacking the new donor organ.

Peter Medawar, a British scientist, worked out why a person's body rejects a transplanted organ. His work led to the first anti-rejection medication, and he received a **Nobel Prize** for this in 1960.

Stem cells may allow new organs to be grown

Current research into the use of some types of cells is exciting for the future of organ transplantation. Stem cells are cells that can produce any other type of cell. They exist in some places in an adult human body, but some of the most powerful stem cells come from embryos.

The potential benefits are huge – imagine if you could grow a new beating heart out of your own adult stem cells! You would not have to worry about organ rejection either. The new heart would have the same DNA as you, so your body would identify the heart as yours.

There are **ethical** concerns, though. If embryonic stem cells are used, the embryo is destroyed afterwards. Some people consider this to be loss of life, because the embryo could have developed into a baby.

Figure 2.34: ▶
In the near future, it may be possible to grow new organs in a laboratory, ready to transplant without problems for patients.



Learning Ladder

Systems of living things

- 1 Identify some of the organs that can be transplanted.
- 2 Describe how organs are currently transported for organ transplantation.
- 3 Discuss an example of where organ transplantation has enabled a person to survive.

Use and influence of science

- 1 Identify a problem that organ transplantation has addressed.
- 2 Describe why Peter Medawar won a Nobel Prize.
- 3 Explain the social impacts of the developments in organ transplantation technology.
- 4 Some cultures believe that using stem cells for research is unethical. Discuss the socio-scientific issues that banning stem cell research could create.
- 5 Research and analyse an example of how information about stem cells in the media has shaped worldviews.

Questioning and predicting

p. 232

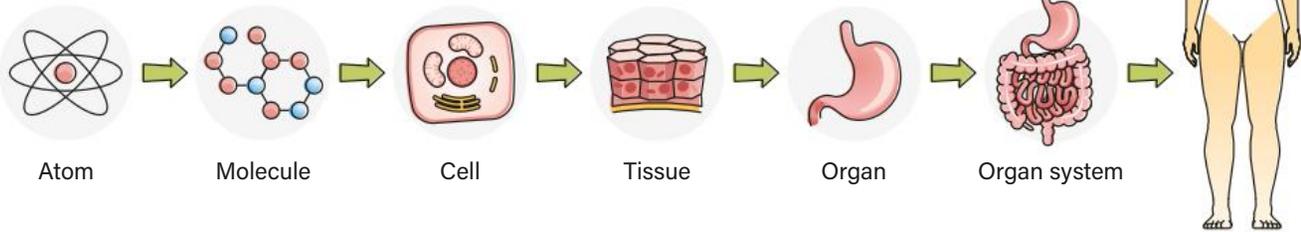
- 1 Propose which of the following questions can be investigated scientifically.
 - A How does the amount of time it takes to transport an organ that is to be transplanted correlate with organ rejection rates?
 - B How many successful heart transplants take place each year in Victoria as compared to other Australian states and territories?
- 2 Make a prediction for the scientific question you selected in Question 1.
- 3 Construct a scientific question to investigate the relationship between the age of heart recipients and the transplant success rate.
- 4 Develop a hypothesis for the question you constructed in Question 3.
- 5 Evaluate your hypothesis from Question 4 by asking the following questions.
 - Is there a clear independent variable?
 - Can the dependent variable be measured with accuracy and precision?
 - Is the predicted effect included in the hypothesis?

Success criteria

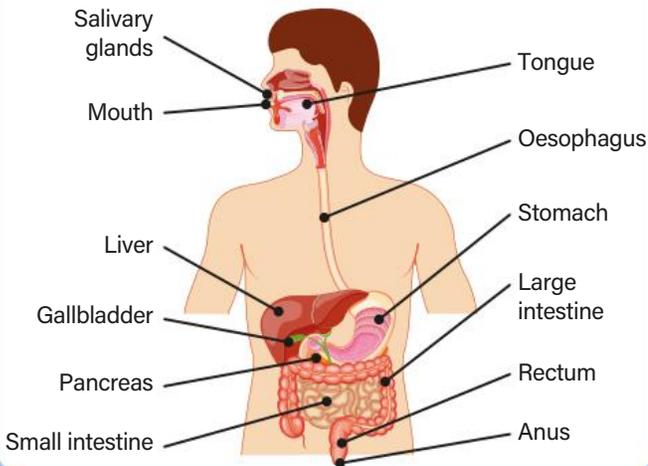
- I can explain how developments in technology have led to improvements in organ transplantation when organ systems fail.

► Summary

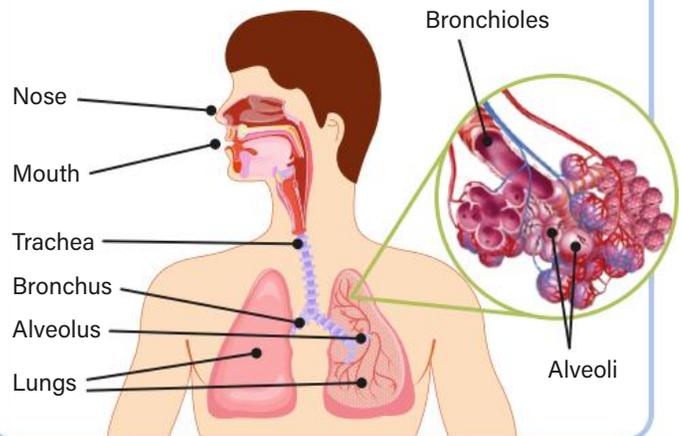
- In organisms made of more than one cell, cells with similar functions group together to form tissues, organs and organ systems.
- Tissues and organs have specialised structures that are related to their function.
- Plant and animal organ systems enable the organism to survive.



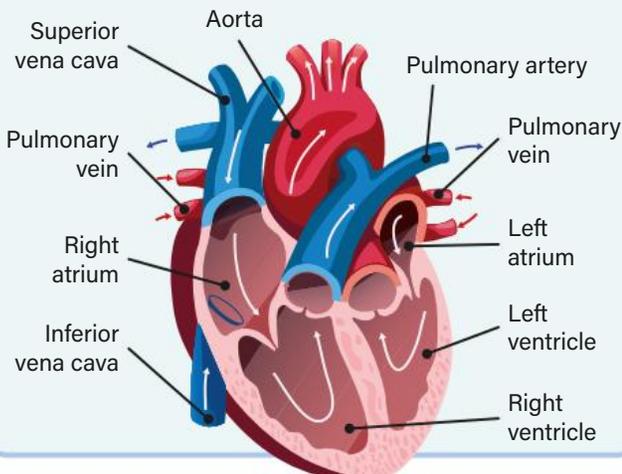
- The role of the **digestive system** is to obtain nutrients and energy from food.



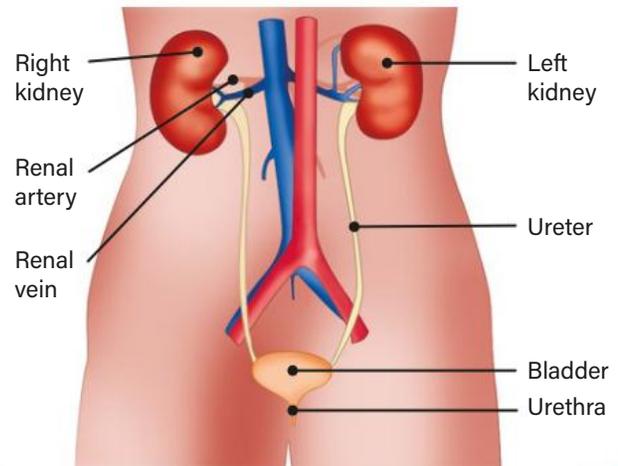
- The role of the **respiratory system** is to bring oxygen into the body and remove waste gases, such as carbon dioxide.



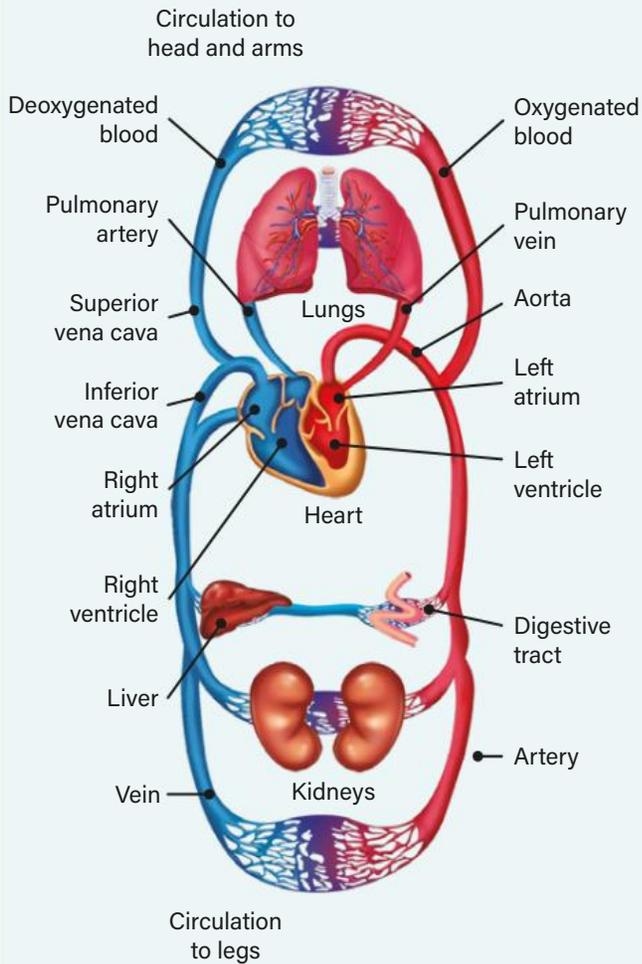
- The role of the **circulatory system** is to transport nutrients and oxygen throughout the body.



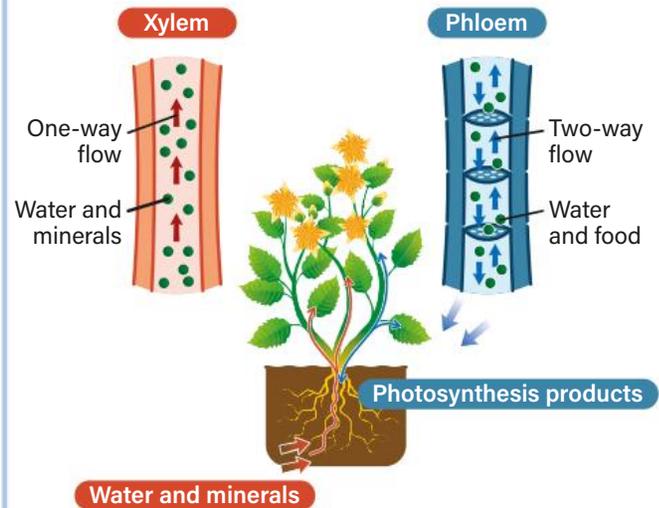
- The role of the **excretory system** is to eliminate cell waste from the body through urine.



- Body systems must work together to provide cells with everything they need to function and survive, such as gases, nutrients and water.

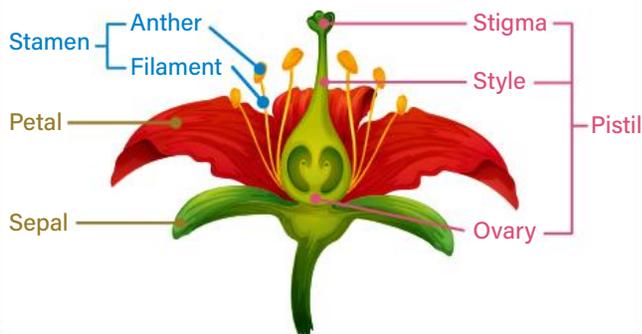


- **Plants** have two organ systems – the root system and the shoot system – made up of roots, stems, leaves and flowers.
- Four main tissue systems (epidermis, vascular, ground, meristematic) include specialised cells with key functions.
- Xylem moves water and nutrients upward; phloem transports substances both up and down.



- In flowering plants, the stamen and pistil work together, allowing pollen transfer and fertilisation to enable plant reproduction and survival.

Parts of a flower



Key idea: Systems

- Advances in science and technology help to replace or support failing body systems, such as through organ transplants and stem cell research.



Masterclass

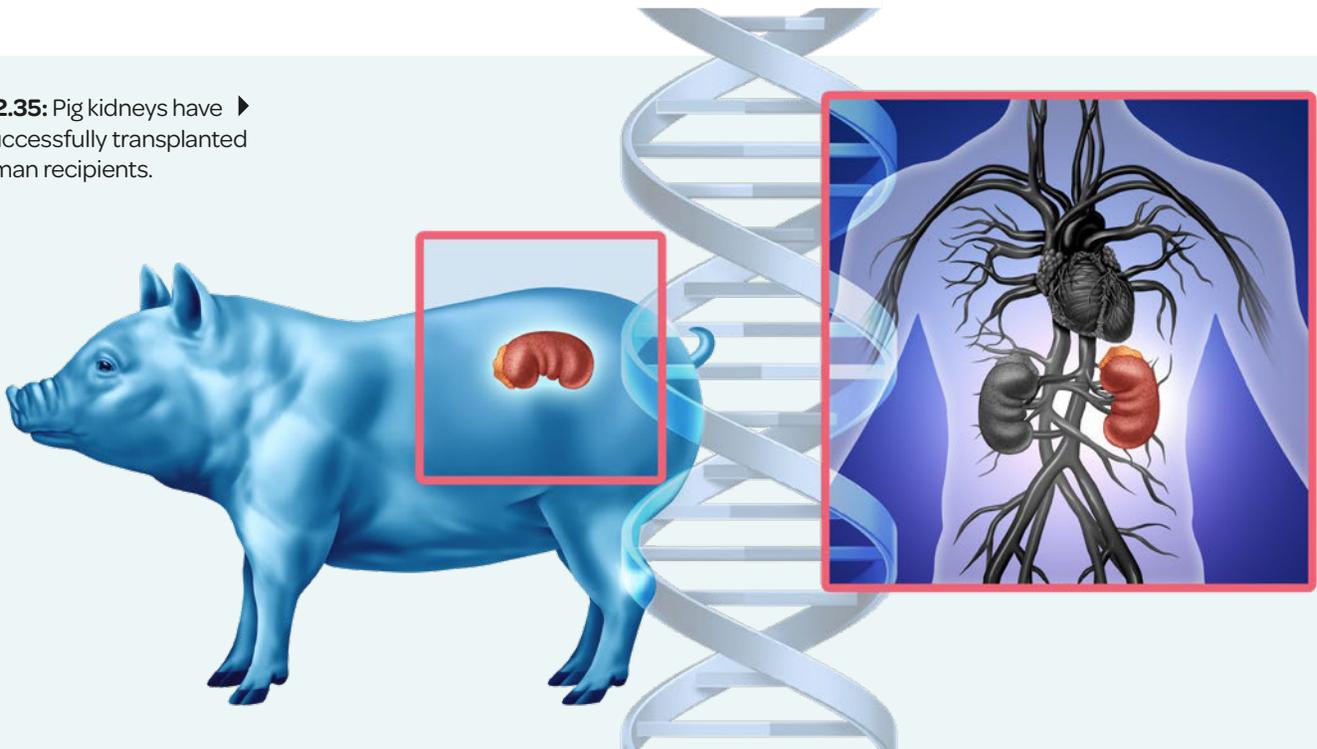
Steps in progression

1

2

Science understanding	Systems of living things	Classify a heart valve as an organ, tissue or cell.	Describe the functional benefits of using pig heart valves in humans.
Science as a human endeavour	Nature and development of science	Identify a problem that xenotransplantation addresses.	Describe why a veterinarian and a cardiologist (heart doctor) might work together on xenotransplantation.
	Use and influence of science	Humans may reject pig organs. Classify this as a social, economic or environmental issue.	Describe how you would feel if xenotransplantation saved your uncle's life.
Science inquiry	Questioning and predicting	True or false? <i>'The following is an example of a question that can be investigated scientifically: Are pig heart valves the same as human heart valves?'</i>	Predict, giving reasons, whether the following animals could be used in xenotransplantation procedures: frog, chimp, warthog, eagle.
	Communicating	Define xenotransplantation. Identify and define three more scientific terms from this section.	Describe why Figure 2.35 is effective in showing what xenotransplantation is.

Figure 2.35: Pig kidneys have been successfully transplanted into human recipients.



Demonstrate your understanding

3

4

5

Explain, using an example, how xenotransplantation can impact more than one organ system at once.	Xenotransplantation increases the risk of infection. Discuss how this might impact your decision to be a recipient.	Analyse why pigs are more suitable for xenotransplantation than whales, in terms of structure and function.	
Propose and explain how evidence of people surviving with pig heart valves may have changed scientific knowledge.	Explain how theories of xenotransplantation have changed and may continue to change over time, starting with pig heart valves.	Analyse how a doctor could disagree with xenotransplantation for ethical reasons but still perform xenotransplantations on patients.	
Explain how a pig kidney being successfully transplanted into a human is a socio-scientific advancement.	A shortage of donor organs led scientists to develop xenotransplantation. Discuss the impacts of this.	Discuss how people's ethics and viewpoints may affect laws and regulations related to xenotransplantation.	
Construct a scientific question that investigates the relationship between the age of a pig and how long its donor valve will last for the recipient.	Develop a hypothesis to predict the outcome of the investigation question constructed in step 3.	Evaluate your hypothesis from step 4. Discuss: <ul style="list-style-type: none"> a Are the independent and dependent variables included? b Is the predicted effect included? c Can you justify the hypothesis using theory? 	Science how-to p. 232
Construct an infographic that displays examples of xenotransplantation.	Construct a video advertisement to educate the public about xenotransplantation.	Adapt your video in step 4 to highlight the ethical aspects of xenotransplantation.	Science how-to p. 255

From pig to patient: xenotransplantation

Did you know that doctors can use animal organs to help save human lives? This process is called xenotransplantation, and it means transplanting organs, tissues or even cells from one species to another. Scientists often use pig organs for this purpose, because they are similar in size and function to human organs. For example, pig heart valves have been successfully implanted in people with heart problems for decades! These valves help to pump blood around the body, just like a human heart valve would, keeping the recipient alive. In another case, doctors recently successfully transplanted a pig kidney into a human patient. This research could help thousands of people who need organ transplants but cannot find a human donor in time. Pig skin has even been used to treat burn victims, acting as a temporary 'bandage' while their own damaged skin heals.

But using animal organs in humans is not just about medicine – it also raises ethical questions. Some people worry about the risks of infections or whether it is right to use animals in this way. Scientists are working hard to ensure that xenotransplantation is safe and ethical. So, it is possible that animal organs could one day become a regular part of human medicine!

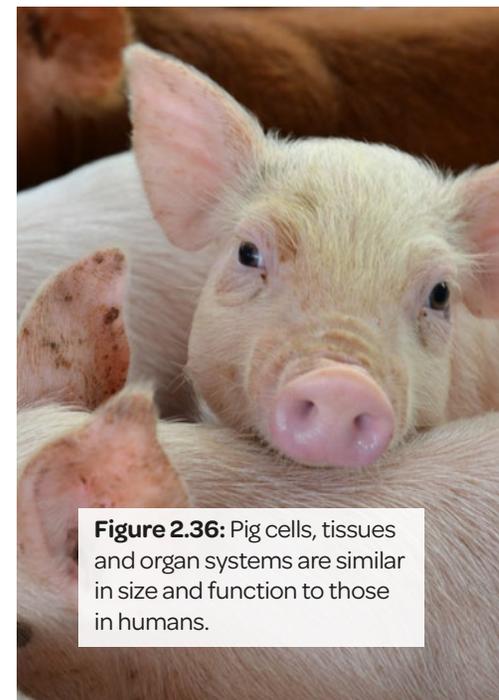


Figure 2.36: Pig cells, tissues and organ systems are similar in size and function to those in humans.

3.0 Organising matter

Matter is anything that takes up space and has mass – from the air you breathe to the phone in your hand. In this chapter, we will dive into the atomic theory of matter to explore the tiny building blocks that make up our world. You will discover the difference between elements, compounds and mixtures, and learn how scientists use models and symbols to represent them. You will be able to ‘see’ matter in two and three dimensions – even when it is invisible to the naked eye. Get ready to think small so that you can understand something big!

Learning Ladder

The Learning Ladder for each chapter maps the Science Understanding, Science as a Human Endeavour and Science Inquiry strands that will be covered. Each ladder has five levels of progression, called steps. To climb the ladders, you need to develop fluency at each step. This will help you develop the ability to complete tasks that are more complex.

5	I can analyse the use of elements and compounds based on their properties	I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations
4	I can explain how different elements and compounds are used	I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues
3	I can represent substances using models, symbols and chemical formulas	I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances
2	I can distinguish between elements, compounds and mixtures	I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society
1	I can identify that all matter is made of atoms of elements	I can recognise scientific problems and solutions	I can identify socio-scientific issues
Steps in progression	Chemical science: Organising matter	Nature and development of science	Use and influence of science
	Science understanding	Science as a human endeavour	

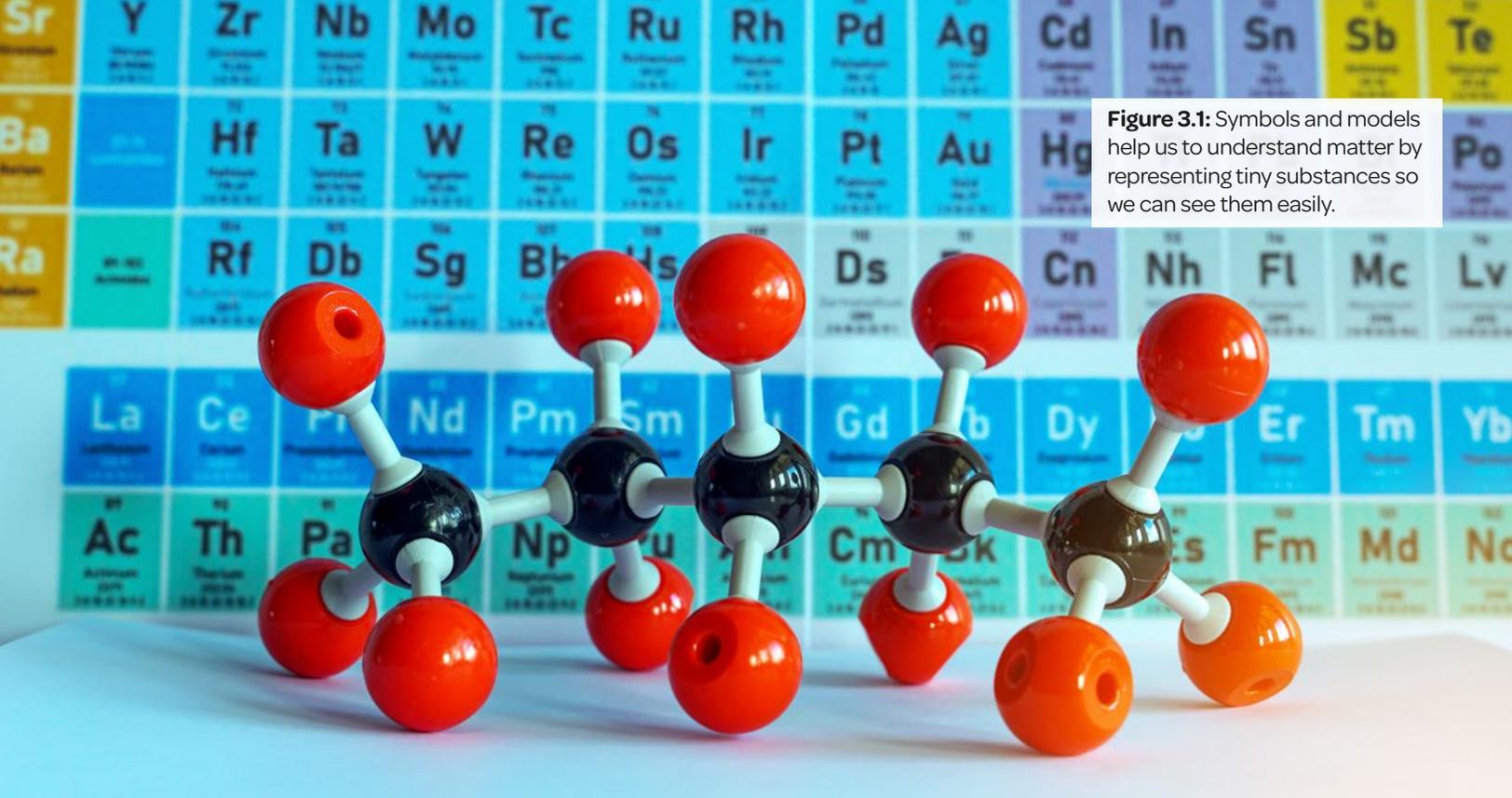


Figure 3.1: Symbols and models help us to understand matter by representing tiny substances so we can see them easily.

<p>I can design and conduct reproducible investigations that consider safety, ethical and procedural factors</p>	<p>I can analyse processed data for patterns, trends, relationships and anomalies</p>	<p>5</p>
<p>I can generate and record data with precision, using digital tools as appropriate</p>	<p>I can identify and discuss trends and/or patterns in a range of dataset representations</p>	<p>4</p>
<p>I can distinguish between variables to be changed, measured and controlled in an investigation</p>	<p>I can process data by using mathematical relationships and/or constructing graphs</p>	<p>3</p>
<p>I can describe ways to minimise risks for a range of investigations</p>	<p>I can organise and display data using tables, keys and/or models</p>	<p>2</p>
<p>I can identify and select appropriate equipment for scientific investigations</p>	<p>I can identify data from tables and graphs</p>	<p>1</p>
<p>Planning and conducting</p>	<p>Processing, modelling and analysing</p>	<p>Steps in progression</p>
<p>Science inquiry</p>		

3.1 ▶ Atomic theory of matter

Learning intention

At the end of this lesson, I will be able to:

- describe Dalton's atomic theory of matter and the aspects of his theory that are still relevant today
- explain the difference between elements, compounds and mixtures.

Key terms

atom: particle that makes up all matter; made up of protons, neutrons and electrons

atomic theory of matter: a theory proposed by John Dalton that all matter is made of atoms

chemical reaction: a rearrangement of the way atoms are joined

compound: a combination of two or more different elements, joined together in a fixed ratio

electrically neutral: having an equal number of protons (positively charged) and electrons (negatively charged)

electron: a subatomic particle that orbits the nucleus of an atom; it is negatively charged

element: a pure substance made of only one type of atom

impure substance: two or more different substances mixed together without a fixed chemical makeup

matter: any substance that has mass and volume (takes up space)

mixture: two or more substances that are combined but retain their own properties and can be physically separated

molecule: a distinct particle made up of two or more atoms chemically joined to each other

neutron: a subatomic particle located in the nucleus of an atom; it is neutrally charged

nucleus: the centre of an atom, which contains protons and neutrons

property: characteristic of a substance that can be observed

proton: a subatomic particle located in the nucleus of an atom; it is positively charged

pure substance: matter that has a fixed chemical makeup

subatomic particles: particles that make up atoms: protons, neutrons and electrons

Key idea: Patterns, order and organisation

In 1803, the English chemist John Dalton began developing his **atomic theory of matter**, which says:

- All matter is made of **atoms** that are indivisible and indestructible (i.e. they cannot be divided or destroyed).
- All atoms of a given element are identical in terms of their mass and properties.
- Compounds are formed by a combination of two or more different kinds of atoms.
- A **chemical reaction** is a rearrangement of atoms.

Although we have a much better understanding of the atom today, the main aspects of Dalton's theory are still accepted as true.



Figure 3.2: There are more atoms in a single grain of sand than there are grains of sand on an entire beach.

Matter is made up of atoms

Everything that you see around you is made of **matter**. Imagine you are sitting on a beach and looking at your surroundings. You observe three states of matter: liquid (the ocean), gas (the air and clouds) and solid (the sand). You feel the sand grains and notice how tiny each grain is. You wonder if there is anything smaller than this. The answer is 'yes'. The atom is the basic unit of matter. It is so small, you need special equipment to see it. In fact, there are more atoms in a single grain of sand than there are grains of sand on a whole beach!

Dalton proposed that atoms are indivisible and indestructible. We now know that atoms can be broken down into even smaller units called **subatomic particles**. But the basic principle of his theory – that all matter is made up of atoms – still holds true.

Atoms are made up of subatomic particles

What Dalton did not know is that atoms are made up of three types of subatomic particles:

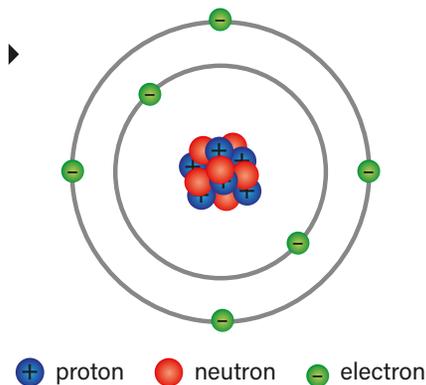
- **protons**, which have a positive charge
- **neutrons**, which have no charge
- **electrons**, which have a negative charge.

Electrons are much smaller than protons and neutrons. This means that almost all the mass of an atom is in its centre, called the **nucleus**. Atoms are held together by strong attractions between the protons and electrons, which are attracted to each other because they are oppositely charged. An atom contains equal numbers of protons and electrons, which means the positive and negative particles cancel each other out. Therefore, atoms are **electrically neutral** – they have no overall charge.

Elements are made up of one type of atom

Elements are **pure substances** made up of only one type of atom. Atoms of one type of element each have the same number of protons. If you change the number of protons, you change the element. For example, atoms of carbon will always have six protons in the nucleus, as shown in Figure 3.3. If an atom has more or fewer than six protons, it is not carbon.

Figure 3.3: Every atom has electrons, and a nucleus that contains protons and neutrons. This carbon atom contains six protons, six neutrons and six electrons.



Dalton proposed that all atoms of a given element are identical in mass and **properties**, which is only partly true. We now know that the mass of atoms of the same element can sometimes differ. (You will learn more about this in later years.) But it is true that the chemical properties of atoms that make up a given element are the same. Carbon atoms, for example, whatever their mass, will all have similar chemical properties. However, if a carbon atom is broken down into its subatomic particles, it no longer has the properties of carbon.

Compounds are made of two or more different elements

Compounds are pure substances made when two or more different types of atoms join together. These atoms come from different elements and are chemically connected. For example, water is a compound made from hydrogen and oxygen atoms. When different elements combine to form compounds, they often have completely different properties than the elements they came from. Table salt, for example, is made from sodium (a metal) and chlorine (a gas), but together they make the white crystals we add to our food!



Figure 3.4: The elements sodium metal and chlorine gas can join together to form the compound sodium chloride, or table salt. Each of these three substances has very distinct properties.

Mixtures are made up of more than one substance

When two or more pure substances are combined but are not chemically joined, it is called a **mixture**. This means that each substance in a mixture keeps its own properties. You can usually separate the different components of a mixture physically, such as by using filters or magnets. For these reasons, a mixture is considered an **impure substance**, without a specific chemical makeup. A fruit salad is a mixture of different fruits, and air is a mixture of gases like oxygen and nitrogen. Mixtures can be made up of elements and/or compounds, and can be solids, liquids or gases. Mixtures are all around us.

Figure 3.5: Matter can be divided into pure substances and impure substances (mixtures).

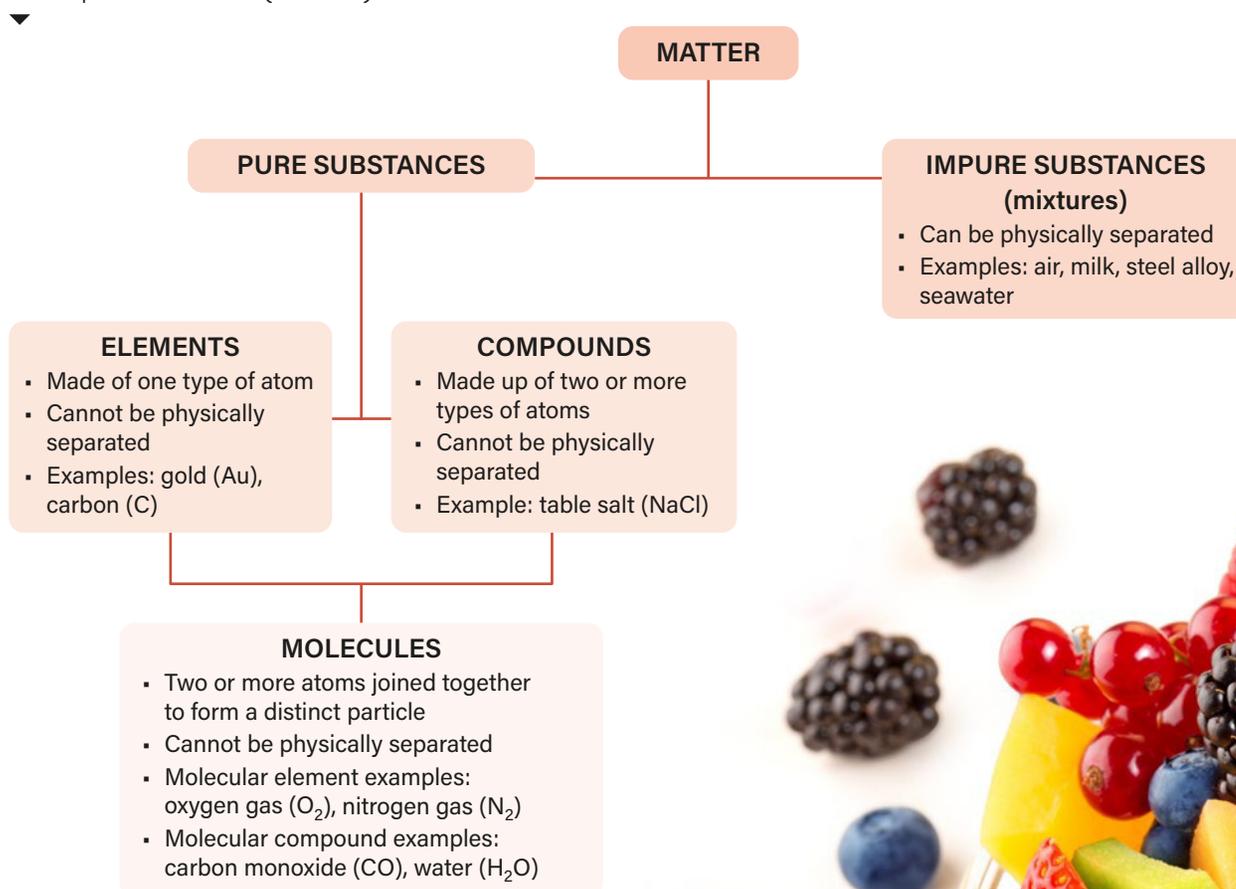


Figure 3.6: Fruit salad is like a mixture. Each type of fruit has distinct properties and can be physically separated from the other fruits.

Matter can be classified

Matter can be classified as pure or impure substances. Elements and compounds are pure substances, while mixtures that can be physically separated are impure substances (Figure 3.5).

A **molecule** is a particle of matter that is made up of more than one atom joined together. The atoms can be of the same type, or different. Therefore, molecules can be elements or compounds. For example, two oxygen atoms can join together to form an oxygen molecule (O_2). Carbon monoxide (CO) is an example of a molecule that is also a compound because it forms a distinct particle and contains atoms of more than one type of element – carbon and oxygen.





A chemical reaction is a rearrangement of atoms

The way atoms are joined to one another determines what the substance is, so when atoms are rearranged, new substances are formed. When this happens, it is called a chemical reaction. John Dalton figured this out over 200 years ago, and it still forms the basis of how we describe chemical reactions today. We will look more closely at chemical reactions in Chapter 4.

◀ **Figure 3.7:** John Dalton

Learning Ladder

Organising matter

- 1 Complete the sentences below.
John _____ proposed that all _____ is made up of _____ and that atoms of a given _____ are identical. This became part of the _____ theory of _____.
- 2 **a** Describe the difference between an element and a compound.
b Describe, using examples, how a molecule can be an element or a compound.
- 3 Construct a labelled diagram of a helium atom which has two protons, two neutrons and two electrons.

Nature and development of science

- 1 Complete the sentences below.
Dalton was able to understand _____ as the basic unit of _____, even before there was sophisticated technology. He figured out that _____ are made of one type of atom and _____ contain more than one type.
- 2 **a** Propose three types of scientists that Dalton may have worked with to develop the atomic theory of matter.
b Propose and describe how the contributions of those scientists may have been important.
- 3 Explain how the discovery of subatomic particles led to further developments of Dalton's theory.
- 4 Propose and discuss why using and understanding models of atoms is important.

- 5 Figure 3.5 shows how matter is commonly classified into different types of substances. Analyse how a tool like this enables people with different perspectives and worldviews to work together to develop scientific knowledge.

Processing, modelling and analysing p. 240

- 1 Identify how many categories there are of pure substances. Name them.
- 2 Refer to Figure 3.6.
a Construct a table to organise the components (types of fruit) in the fruit salad mixture.
b Use tally marks to count how many of each type of fruit you can see in the image.
- 3 Construct a pie chart to represent the percentage of each type of fruit identified in the mixture. If you need help with constructing the chart, see pages 283–84 in the Science how-to section.

Key idea: Patterns, order and organisation

The progression of atomic structure from the simplest atom to the most complex atom follows a pattern. Conduct an online search to determine this pattern.

Success criteria

- I can describe Dalton's atomic theory of matter and identify which aspects are still accurate today.
- I can distinguish between elements, compounds and mixtures.

3.2 ▶ Classifying elements

Figure 3.8: Aluminium is a strong, malleable metal, which means it is a good material for packaging food and drinks.

Learning intention

At the end of this lesson, I will be able to:

- represent elements using symbols from the Periodic Table
- distinguish between metal and non-metal elements based on their properties and position in the Periodic Table.

Key terms

atomic number: the number of protons in an atom, used to organise elements into the Periodic Table

brittle: not able to be bent; will break or shatter if stressed

chemical symbol: a letter or pair of letters used to represent a chemical element

ductile: can be drawn out into a wire

malleable: able to be bent and shaped

metalloid: an element with properties of both metals and non-metals

Periodic Table: a table of the chemical elements arranged in order of atomic number from 1 to 118

Investigation 3.2

Comparing metals and non-metals, p. 309

Key idea: Patterns, order and organisation

There are over 100 different elements. Each one has its own type of atom with a specific number of protons in the nucleus. The Periodic Table that we use today organises elements by their number of protons (their **atomic number**), from 1 to 118. (Section 3.8, later in this chapter, provides an overview of the historical development of periodic tables.) Each element has a unique name and symbol, and it can generally be classified into two groups: metals and non-metals. Both metals and non-metals have distinct properties.

Elements can be represented by their symbols

The **Periodic Table** organises information for every known element in the universe. Elements in the Periodic Table are arranged by their atomic number, which is equal to the number of protons in the nucleus of an atom of the element. Hydrogen atoms have one proton in their nucleus; therefore, hydrogen's atomic number is 1.

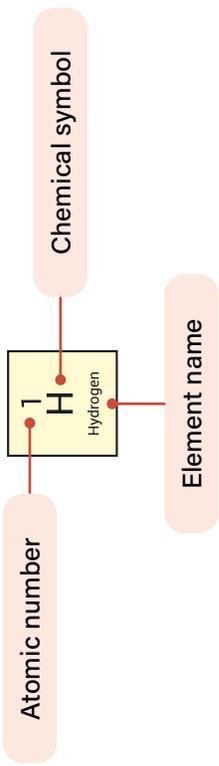
The Periodic Table also displays the symbol for each element, which is universal. This means it is always the same, no matter where you are in the world. These abbreviations are called **chemical symbols** and are made up of one or two letters. The first letter is always a capital. If the symbol has a second letter, it is always lowercase. This is very important when representing elements using their symbols. For instance, the chemical symbol for cobalt is Co; capital 'C' and lowercase 'o'. If you accidentally use capital letters for both – that is, CO – this would be incorrectly interpreted as carbon (C) and oxygen (O).

Figure 3.9: Elements are organised into the Periodic Table by their atomic number. The red zig-zag line generally separates metals and non-metals, with the exception of hydrogen, which is a non-metal even though it is located among the metals.

1 H Hydrogen	2 He Helium
3 Li Lithium	4 Be Beryllium
11 Na Sodium	12 Mg Magnesium
19 K Potassium	20 Ca Calcium
37 Rb Rubidium	38 Sr Strontium
55 Cs Cesium	56 Ba Barium
87 Fr Francium	88 Ra Radium
21 Sc Scandium	22 Ti Titanium
39 Y Yttrium	40 Zr Zirconium
57 La Lanthanum	58 Ce Cerium
89 Ac Actinium	90 Th Thorium
23 V Vanadium	24 Cr Chromium
41 Nb Niobium	42 Mo Molybdenum
73 Ta Tantalum	74 W Tungsten
105 Db Dubnium	106 Sg Seaborgium
107 Bh Bohrium	108 Hs Hassium
109 Mt Meitnerium	110 Ds Darmstadtium
111 Rg Roentgenium	112 Cn Copernicium
77 Ir Iridium	78 Pt Platinum
109 Mt Meitnerium	110 Ds Darmstadtium
111 Rg Roentgenium	112 Cn Copernicium
79 Au Gold	80 Hg Mercury
111 Rg Roentgenium	112 Cn Copernicium
43 Tc Technetium	44 Ru Ruthenium
75 Re Rhenium	76 Os Osmium
107 Bh Bohrium	108 Hs Hassium
45 Rh Rhodium	46 Pd Palladium
77 Ir Iridium	78 Pt Platinum
109 Mt Meitnerium	110 Ds Darmstadtium
47 Ag Silver	48 Cd Cadmium
79 Au Gold	80 Hg Mercury
111 Rg Roentgenium	112 Cn Copernicium
27 Co Cobalt	28 Ni Nickel
45 Rh Rhodium	46 Pd Palladium
77 Ir Iridium	78 Pt Platinum
109 Mt Meitnerium	110 Ds Darmstadtium
29 Cu Copper	30 Zn Zinc
47 Ag Silver	48 Cd Cadmium
79 Au Gold	80 Hg Mercury
111 Rg Roentgenium	112 Cn Copernicium
5 B Boron	6 C Carbon
13 Al Aluminium	14 Si Silicon
31 Ga Gallium	32 Ge Germanium
49 In Indium	50 Sn Tin
81 Tl Thallium	82 Pb Lead
113 Nh Nihonium	114 Fl Flerovium
7 N Nitrogen	8 O Oxygen
15 P Phosphorus	16 S Sulfur
33 As Arsenic	34 Se Selenium
51 Sb Antimony	52 Te Tellurium
83 Bi Bismuth	84 Po Polonium
115 Mc Moscovium	116 Lv Livermorium
9 F Fluorine	10 Ne Neon
17 Cl Chlorine	18 Ar Argon
35 Br Bromine	36 Kr Krypton
53 I Iodine	54 Xe Xenon
85 At Astatine	86 Rn Radon
117 Ts Tennessine	118 Og Oganesson

Non-metals

Metals



58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium
90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

- metals
- non-metals
- metalloids

Non-metal elements share many properties

Non-metal elements share many of the same properties. The properties of non-metal elements include:

- low melting temperature
- poor electrical conductivity
- **brittle** (not **malleable**)
- low boiling temperature
- poor thermal (heat) conductivity (heat does not easily pass through the element)
- dull in appearance (not shiny).

Figure 3.10: Sulfur is a non-metal element; it is dull yellow in colour and is brittle.



Oxygen is a very common non-metal element. In its standard form, oxygen is a gas. Every animal on Earth needs oxygen to make energy for living cells. Burning things in combustion reactions is another example of something that requires oxygen; without it, we would not be able to use stoves, engines, rockets or gas heaters.

Carbon is another common non-metal element. Pure carbon has several different forms. Diamonds and graphite (the 'lead' in your writing pencil) are both pure carbon. The properties of pure carbon vary, depending on its form. For example, graphite is dull but can conduct electricity, while a diamond does not conduct electricity but is shiny. These are exceptions to the general properties of non-metals.

Figure 3.11: Copper is a metal that is a good conductor of electricity and is malleable, which means it is a good material to be used for electrical wiring.

Metal elements have the opposite properties of non-metal elements

Metal elements generally have the opposite properties of non-metal elements. The properties of metal elements include:

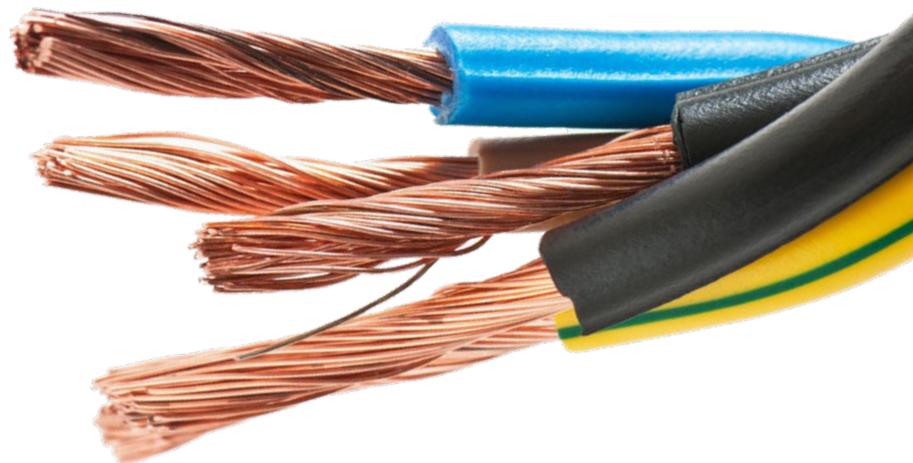
- high melting temperature
- high boiling temperature
- good electrical conductivity
- good thermal (heat) conductivity
- malleable (not brittle)
- lustrous (shiny).

Aluminium is a common metal element. Aluminium is useful because it is very strong and relatively lightweight. This makes it an excellent material for making things such as aircraft and bridges. Aluminium is also used in food packaging and storage – such as in aluminium foil and soft-drink cans – and to protect products (such as some medicines) from air, light and moisture.

Copper is another common metal that is used for many purposes. It is used for electrical wiring because it is a good conductor of electricity and is not only malleable but also **ductile**. This means it can be stretched out into a long wire without breaking.

Metalloids have properties of both metals and non-metals

There are several elements that cannot be easily classified as either a metal or a non-metal because they have properties of both. These elements are called **metalloids**. Metalloids are usually brittle solids. Metalloids can be used in many ways. For example, silicon is a semi-conductor of electricity, meaning it has insulator properties but can also conduct electricity under certain conditions.



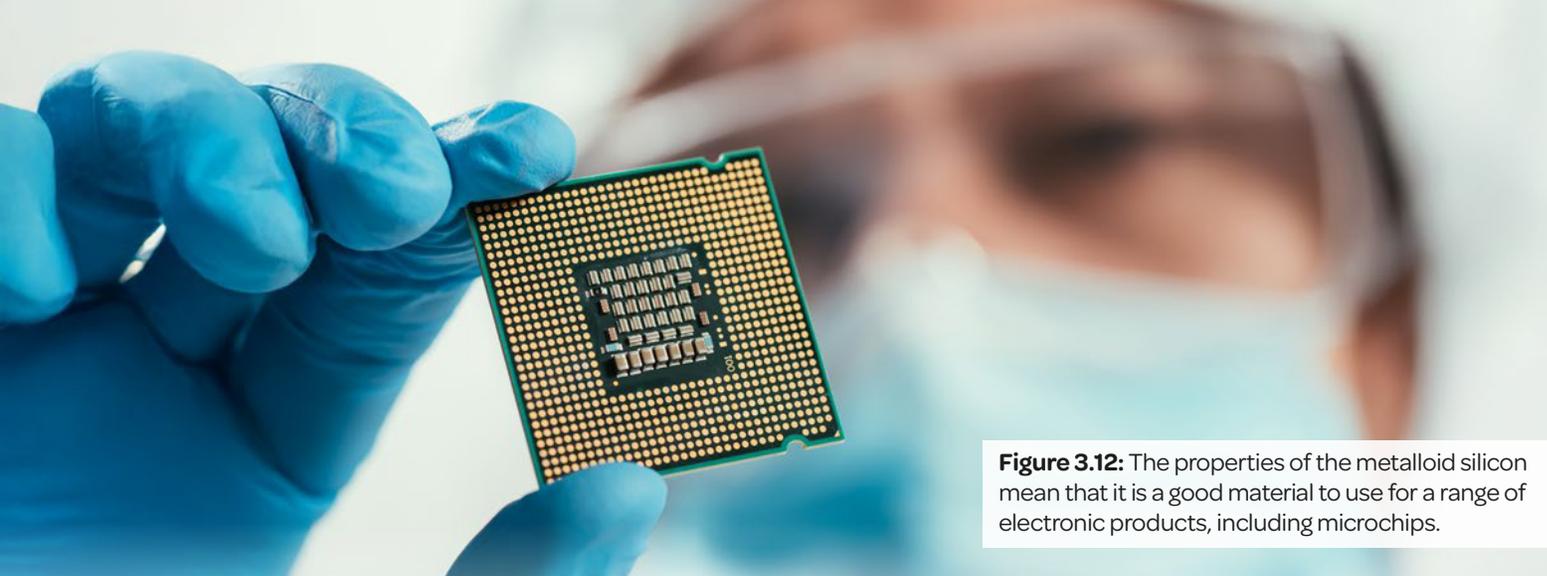


Figure 3.12: The properties of the metalloid silicon mean that it is a good material to use for a range of electronic products, including microchips.

Learning Ladder

Organising matter

- 1 Identify the characteristic of an atom that enables elements to be organised into the Periodic Table.
- 2 Complete the sentences below.
 - a _____ are _____ (pure/impure) substances that can generally be classified as _____ or _____.
 - b If you know an element's _____, you can use the _____ Table to determine if it is a _____ or a non-metal. Otherwise, you could test its properties.
- 3 a Use the Periodic Table to write the chemical symbol for the following elements and classify each as metal or non-metal.
 - i Boron ii Fluorine iii Sodium iv Copper
 - b For each of the following, determine the element name based on the chemical symbol and classify each as metal or non-metal.
 - i K ii P iii Br iv Au
 - c Explain the confusion that would arise if you wrote the symbol for zinc using only capital letters.
- 2 a Identify a hazard for each of the equipment items listed in Question 1.
 - b Describe a way to minimise the risk of each hazard.
- 3 Identify and describe the following:
 - a one independent variable
 - b one dependent variable
 - c three controlled variables.
- 4 a Propose a digital tool that could be used to measure conductivity more precisely, in place of the light bulb.
 - b Discuss how using this tool would change the data generated and recorded.
 - c Propose and explain how using this tool would require adaptations to the results table.
- 5 Adapt the the method for Investigation 3.2 to investigate the properties of different types of metals with quantitative precision. *Hint:* How might you quantify the malleability of a substance? Be sure to consider safety and ethical factors.

Key idea: Patterns, order and organisation

Charcoal and diamonds are two forms of pure carbon. Investigate how the carbon atoms are organised in each substance. Discuss the patterns that are identified and relate the patterns to their properties and how they are used in society. Are there any other substances made up of pure carbon?

Success criteria

- I can identify and represent elements using the Periodic Table.
- I can classify elements as metal or non-metal based on their properties and position in the Periodic Table.

Nature and development of science

- 1 Elements have been discovered in many parts of the world. Identify how they are able to be identified universally.
- 2 Propose and describe the importance of chemists and nuclear scientists working together to organise elements into the Periodic Table.

Planning and conducting

p. 236

Read Investigation 3.2 on page 309 and then answer the following questions.

- 1 Arrange the equipment items in order of how likely you think they are to cause injury or harm during the investigation. Provide reasons for the order you have proposed.

3.3 ▶ Chemical formulas and common compounds

Figure 3.13: We use the common compound sodium chloride every day.

Learning intention

At the end of this lesson, I will be able to:

- identify the ratio of atoms in a compound from its chemical formula
- identify some examples of common compounds and their uses.

Key terms

chemical formula: an expression of the elements that make up a chemical compound, usually presented as a ratio using chemical symbols and numbers – for example, H_2O

crystalline: having the structure and form of a crystal

Investigation 3.3

Investigating the different properties of a compound and one of its elements, p. 310

Key idea: Patterns, order and organisation

Recall that an element is a pure substance made of one type of atom, and a compound is a pure substance made of atoms from two or more elements joined together. For example, carbon and oxygen are pure elements, while carbon dioxide is a compound made up of carbon and oxygen atoms chemically joined. As you learnt in the previous section, elements on their own are represented by their chemical symbol from the Periodic Table. But when two or more atoms are joined together, they can be represented by their **chemical formula**.

Chemical formulas show the ratio of atoms in a compound

Compounds contain atoms in a fixed ratio and are often referred to by their chemical formulas. These formulas are expressed using chemical symbols and subscript numbers. The number of atoms is indicated by the subscript number after the chemical symbol. If there is no number following a chemical symbol, it means there is just one atom. The number 1 is never shown as a subscript in chemical formulas.

Water has the chemical formula H_2O ; the subscript 2 tells us there are two hydrogen (H) atoms. Since there is no subscript number after the 'O', it means there is just one oxygen atom. For every two hydrogen atoms in a sample of water, there is one oxygen (O) atom; this is a 2:1 ratio that will never change. Water will always have a hydrogen-to-oxygen ratio of 2:1.

If you change the ratio of atoms in a compound, you change the substance altogether. For instance, if you join another oxygen atom (O) to a water molecule (H_2O), it is no longer water. It is now H_2O_2 , which is hydrogen peroxide (a common antiseptic).

We will now take a look at some other common compounds, their chemical formulas and how they are relevant to everyday life.

Figure 3.14: Water is a compound made up of the elements oxygen and hydrogen.

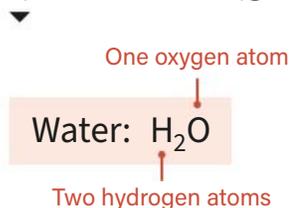


Table 3.1: The ratio of atoms in a compound determines the substance. H₂O is water, while H₂O₂ is hydrogen peroxide.

Compounds that contain hydrogen and oxygen	Structure	Hydrogen-to-oxygen ratio (H:O)	Chemical formula
Water		2:1	H ₂ O
Hydrogen peroxide		2:2 (simplify by dividing by 2) 1:1	H ₂ O ₂

Carbon dioxide is a compound that is essential for plants

Carbon dioxide is another compound that is essential to life. Humans and other animals breathe in oxygen and breathe out carbon dioxide as a waste product. Plants use carbon dioxide to make energy to survive. Carbon dioxide is a gas at room temperature. Each carbon dioxide molecule contains one carbon atom bonded to two oxygen atoms. This is a 1:2 ratio.

Figure 3.15: Carbon dioxide is a compound made up of carbon and oxygen in a 1:2 ratio indicated by the subscript values.

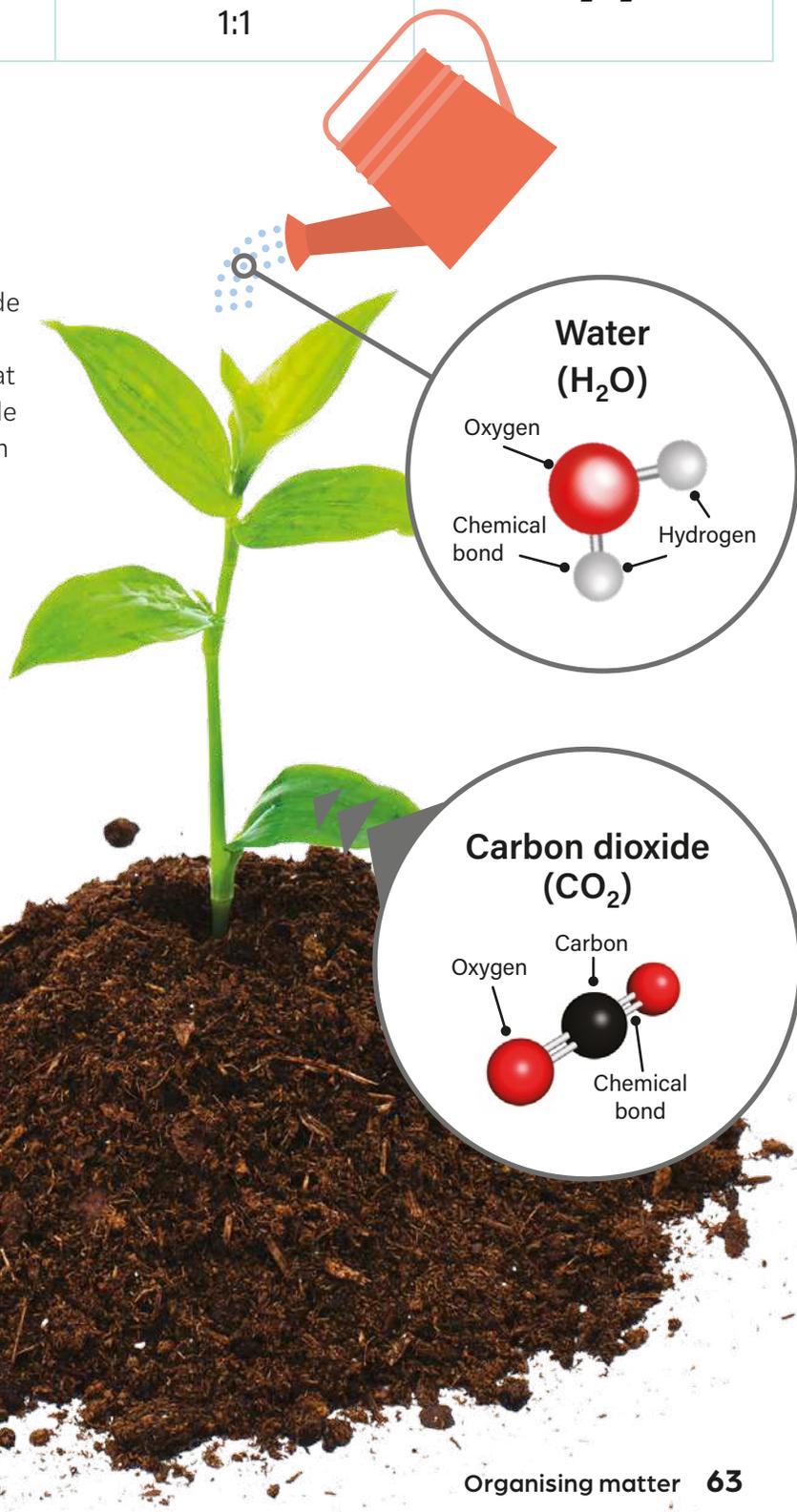
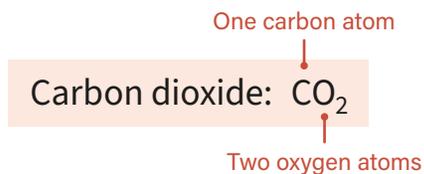


Figure 3.16: ▶ Plants need sunlight, carbon dioxide and water to survive and grow.

Ammonia is a compound used in farm and household products

Ammonia is used to make products such as fertilisers, which help plants to grow, and cleaning products. At room temperature, ammonia is a poisonous gas. Ammonia is made safer in agriculture by combining it with other compounds to form ammonium salts, which are solid, white granules when they are at room temperature. Each ammonia molecule is made up of one nitrogen atom joined to three hydrogen atoms. This is a 1:3 ratio.

Figure 3.17: Ammonia is a compound made up of nitrogen and hydrogen in a 1:3 ratio indicated by the subscript values.

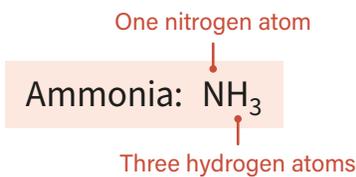
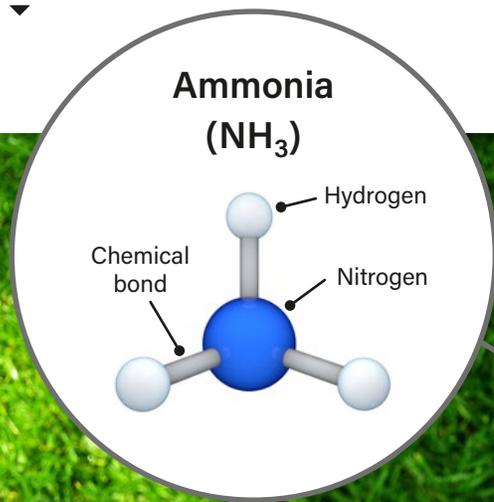


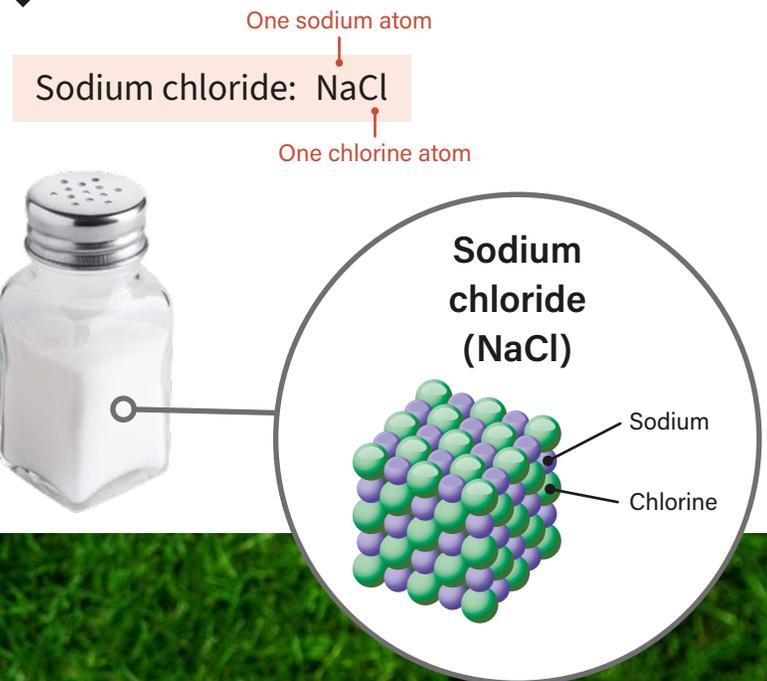
Figure 3.18: Ammonia is used to make fertilisers, which help crops to grow.



Sodium chloride is a compound used in many foods

Sodium chloride (NaCl) is better known as table salt. In sodium chloride, for every one sodium atom there is one chlorine atom. This is a 1:1 ratio. Sodium chloride is a compound that does not form molecules but has a three-dimensional **crystalline** structure, with alternating sodium and chlorine atoms (see Figure 3.19).

Figure 3.19: Sodium chloride is a compound made up of sodium and chlorine in a 1:1 ratio indicated by the absence of subscript values.



Learning Ladder

Organising matter

- a** Identify the elements in the following substances.
 - Water
 - Carbon dioxide
 - Ammonia
 - Sodium chloride**b** Identify the total number of atoms in a molecule of the following substances.
 - Water
 - Carbon dioxide
 - Ammonia
 - Sodium chloride
- Classify each of the following substances as either a compound or an element.
 - Carbon monoxide (CO)
 - Hydrogen gas (H₂)
 - Gold metal (Au)
- a** Identify the ratio of atoms in each of the following substances, based on their chemical formula.
Hint: Write the ratio numbers in the order their symbols appear, separated by a colon (e.g. aluminium oxide (Al₂O₃) = Al:O is 2:3).
 - Magnesium chloride (MgCl₂)
 - Sulfuric acid (H₂SO₄)
 - Butane (C₄H₁₀)
 - Calcium nitrate Ca(NO₃)₂**b** Predict and sketch the structure of a methane molecule (CH₄), given carbon as the central atom, and identify the C:H ratio.
- Select one of the compounds mentioned in this section and explain why it is essential to everyday life.

Nature and development of science

- Propose a problem that could arise if subscripts were not included in chemical formulas.
- Describe how having universal names and chemical formulas for compounds makes it easier for different types of scientists from different countries to work together.
- Explain how a scientist with new evidence about the formula of a chemical compound may share that evidence and influence others to change the formula.
- a** Undertake the following research.
 - Identify the person who discovered that water is made up of hydrogen and oxygen. Describe when and how they made this discovery.
 - Identify the person who demonstrated that water is a compound, not an element. Describe when and how they made this discovery.
 - Identify the person who clarified that water has the formula H₂O. Describe when and how they made this discovery.**b** Using this example, discuss how models and theories in science may be developed over time.

Planning and conducting

p. 236

You have been asked to investigate the mass of copper(I) oxide powder compared to the mass of pure copper that is left behind after heating it over a blue flame.

- Propose a list of materials that would be required to conduct this investigation.
- a** Identify at least four hazards presented by the materials proposed in Question 1.
b Describe how you would minimise the risks associated with each hazard identified in part a.
- Copper(II) oxide is a different compound from copper(I) oxide, with a different ratio of atoms. You are asked to repeat the investigation with copper(II) oxide and to compare the data to the first investigation. Assume that these two investigations were combined.
 - Identify the independent variable.
 - Identify the dependent variable, including units of measurement.
 - Describe at least three controlled variables.
- To record the mass of the copper oxides, you have a choice between electronic balances with either two or three decimal places. Justify which balance you would choose to use, making reference to precision and accuracy.
- Construct a step-by-step method for this investigation which could be safely and ethically followed by a fellow Year 8 student to collect precise data.

Key idea: Patterns, order and organisation

The first four members of a family of hydrocarbons called alkanes are methane (CH₄), ethane (C₂H₆), propane (C₃H₈) and butane (C₄H₁₀).

- Identify the pattern in the four chemical formulas.
- Predict the chemical formula of the fifth member of the hydrocarbon family: pentane.
- Propose a general formula for hydrocarbon alkanes that could be used to determine the number of hydrogen atoms, given the number of carbon atoms.

Success criteria

- I can identify the ratio of atoms in a compound based on its chemical formula.
- I can identify some common compounds and their uses.

3.4 ▶ Types of mixtures

Learning intention

At the end of this lesson, I will be able to:

- identify and describe different types of mixtures, including solutions, alloys, suspensions and colloids
- explain why mixtures are represented by percentages
- calculate mass per cent (%m/m) given the mass of the part and the mass of the mixture.

Key terms

alloy: a metal mixed with another element

brass: an alloy made of copper and zinc

colloid: a mixture made of tiny insoluble parts

heterogeneous: a mixture with an uneven (non-uniform) composition

homogeneous: a mixture with an even (uniform) composition

insoluble: unable to dissolve

mass: the amount of matter something contains, often measured in grams (g)

mass per cent: the ratio of the mass of a part of a mixture, relative to the total mass, expressed as a percentage

solute: a substance that is dissolved by a solvent

solution: a mixture made up of a solute and a solvent

solvent: a substance that a solute dissolves in

suspension: a mixture made of large insoluble parts

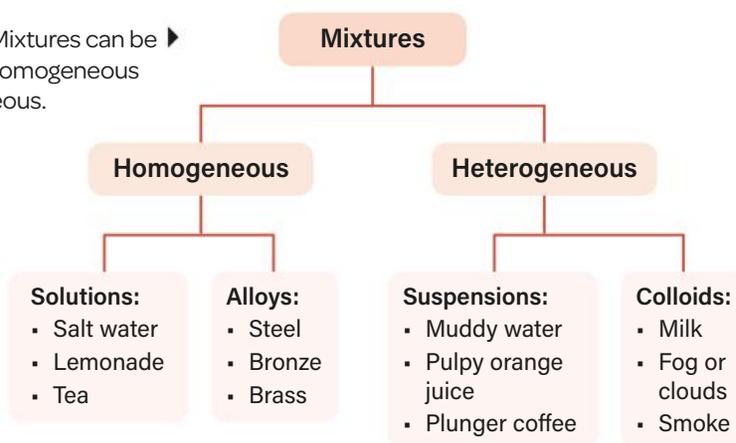
Investigation 3.4

Separating a mixture, p. 312

Key idea: Patterns, order and organisation

Mixtures are impure substances that come in many forms, depending on their parts and how they are combined. Unlike compounds, mixtures are not in a fixed ratio; each component can vary in amount and keeps its own properties. In this section, you will explore types of mixtures and learn how they are often described using percentages.

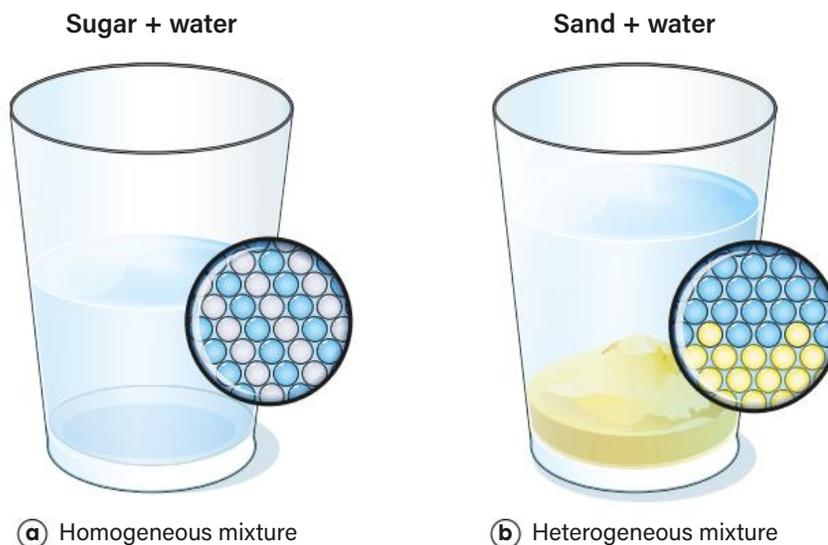
Figure 3.20: Mixtures can be classified as homogeneous or heterogeneous.



Mixtures can be homogeneous or heterogeneous

Mixtures can be grouped into two main types: homogeneous and heterogeneous. In a **homogeneous** mixture, the substances are evenly mixed and look the same throughout, like sugar dissolved in water. In a **heterogeneous** mixture, the substances are not evenly mixed and you can often see the different parts, like sand in water.

▼ **Figure 3.21:** Homogeneous and heterogeneous mixtures



Solutions and alloys are types of homogeneous mixtures

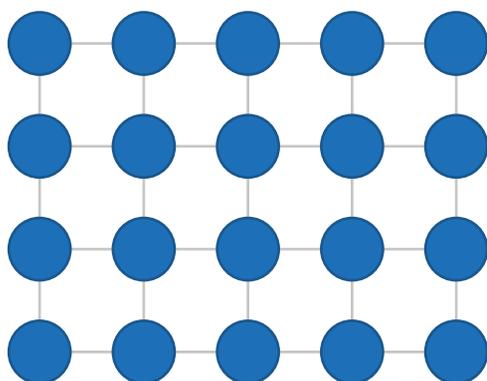
When a **solute** dissolves in a **solvent**, this forms a **solution**, which is a common type of homogeneous mixture. For example, when sugar (the solute) dissolves in water (the solvent), it forms a clear, uniform solution, as shown in Figure 3.21(a).

An **alloy** is a metal mixed with another element (usually a different metal or carbon). This is also a type of homogeneous mixture. Metals such as copper and zinc can mix to form **brass**, while iron and carbon combine to make steel; both alloys are mixtures with no visible parts and are therefore considered homogeneous.

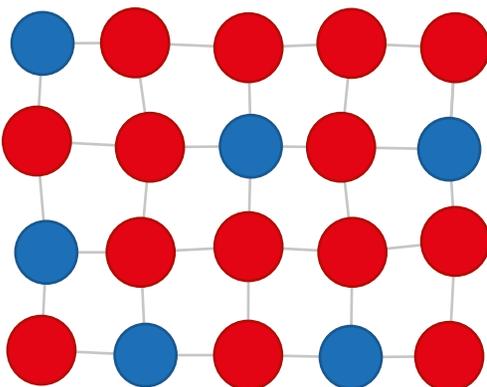
Copper and zinc particles in brass alloy are not the same size, so when they are combined, the rows of metal particles become distorted, as shown in Figure 3.22(b). This produces a harder metal because the rows become more rigid.

Figure 3.22: Alloys are formed when a pure metal is mixed with another element.

▼
a) A pure metal has rows of identical particles.



b) An alloy has different-sized particles, which disrupts the rows in the metal, altering the overall properties.



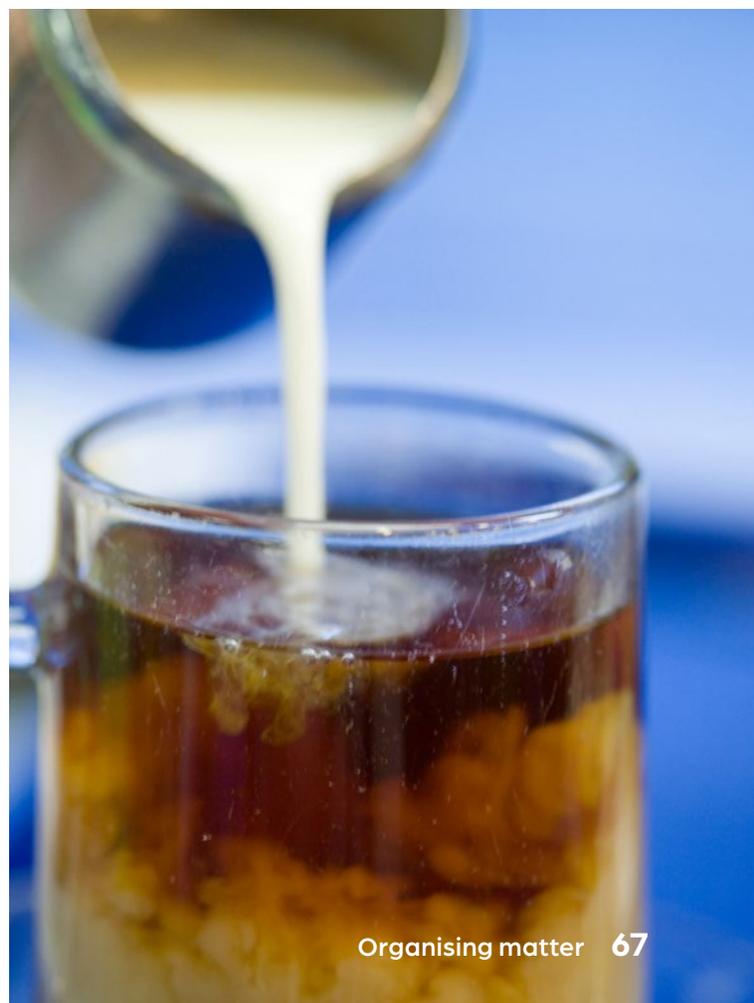
Suspensions and colloids are types of heterogeneous mixtures

Heterogeneous mixtures often look cloudy, lumpy or uneven due to the **insoluble** particles that remain visible. Two types of heterogeneous mixtures are suspensions and colloids.

Suspensions contain relatively large particles that do not dissolve in the liquid or gas they are mixed with. These particles are heavy enough to settle to the bottom over time if the mixture is left undisturbed. A common example is sand in water. It looks evenly mixed at first, but after a while, the sand sinks to the bottom. The same thing happens with coffee grounds in a plunger.

Colloids, on the other hand, have insoluble particles that are small enough to remain evenly spread throughout the mixture. The particles do not settle quickly, so the mixture stays looking cloudy or creamy. Examples of colloids include milk, fog and smoke.

Figure 3.23: Tea is a clear, homogeneous solution, but when milk (a colloid) is added, it becomes cloudy and less able to transmit light due to the insoluble particles suspended in solution.



Mixtures can be represented by percentages

Unlike compounds, mixtures do not have fixed ratios. This means the amounts of substances in a mixture can change, without changing the type of mixture itself. To describe how much of each substance is present, we use percentages. Percentages help us to compare and understand mixtures, no matter how much of each part is present.

For example, orange juice with pulp is a heterogeneous suspension. One glass might have 5 per cent pulp and another 10 per cent, depending on how it is made. Although the percentages are different, it is still the same type of mixture – orange juice.

In metal alloys, the percentages of metals can also vary depending on the desired properties. Brass is made from copper and zinc, but it might be 70 per cent copper and 30 per cent zinc in one case, or 60 per cent copper and 40 per cent zinc in another. Both are still brass. Table 3.2 shows the composition of three different variations of brass alloy.

Table 3.2: The compositions of different types of brass alloy

Type of brass alloy	Percentage composition of elements (%)		Uses
	Copper	Zinc	
Gilding metal	95	5	<ul style="list-style-type: none"> bullet jackets decorative doors, railings and trim jewellery
Cartridge brass	70	30	<ul style="list-style-type: none"> ammunition cartridges electrical applications plumbing applications
Muntz metal	60	40	<ul style="list-style-type: none"> marine applications (e.g. pier piles) trumpets and other musical instruments architectural applications (doors, elevator)

Percentages of mixtures are often based on mass

When representing the composition of a mixture using percentages, it is usually based on how much of each substance is present by **mass**. For example, if a metal alloy is 70 per cent copper and 30 per cent zinc by mass, it means 70 grams out of every 100 grams is copper. This method is useful because different substances can take up different amounts of space, even if they weigh the same. Mass provides a consistent way to determine and interpret the percentage composition used to represent a mixture.

A common expression for **mass per cent** is '%m/m'. This reiterates that the mass of the solute, or the part in question, is divided by the total mass and then multiplied by 100 to make it a percentage.

$$\%m/m = \frac{\text{mass of the solute or part (g)}}{\text{mass of the whole mixture (g)}} \times 100\%$$



Example 1:

What is the percentage of copper by mass in a 200 g sample of brass if it is known to contain 140 g of copper?

mass of copper (part) = 140 g

mass of brass (alloy mixture) = 200 g

$$\begin{aligned}\%m/m &= \frac{\text{mass of copper}}{\text{mass of mixture}} \times 100\% \\ &= \frac{140}{200} \times 100\% \\ &= 70\%\end{aligned}$$

Example 2:

What is the mass per cent (%m/m) of a 250 mL solution with 20 g of salt dissolved in water?

Hint: 1 millilitre of solution weighs about 1 gram;
therefore, **1 mL = 1 g**

mass of salt (solute) = 20 g

mass of solution (mixture) = 250 g

$$\begin{aligned}\%m/m &= \frac{\text{mass of salt}}{\text{mass of solution}} \times 100\% \\ &= \frac{20}{250} \times 100\% \\ &= 8\%\end{aligned}$$

Learning Ladder

Organising matter

- Complete the sentences below.
Homogeneous and _____ are both types of _____ that do not exist in fixed _____. They differ from _____ because the atoms of separate _____ in mixtures are not chemically joined.
- a** Classify each of the following mixtures as either homogeneous or heterogeneous.
i Muddy water **ii** Blood
iii Cereal and milk **iv** Soft drink
v Bronze metal **vi** Clouds
b Propose whether each mixture in part a is a solution, alloy, suspension or colloid, giving a reason.
- Construct a diagram of bronze 'bell metal' alloy at the atomic level, which contains 80 per cent copper and 20 per cent tin. *Hint:* Lead particles are slightly bigger than tin particles.

Use and influence of science

- Complete the sentences below.
Mixtures do not have _____ ratios, so chemical _____ are not used to represent mixtures like they are for _____. To address this problem, _____ are used to indicate how much of each part is present in a mixture.
- The expression 'weight' per cent (%w/w) is often used instead of 'mass' per cent because it is more easily understood by society. Describe how using two different expressions for the same thing might be confusing, making specific reference to weight and mass.

Processing, modelling and analysing p. 240

- Use Table 3.2 to identify the mass per cent of:
a copper in gilding metal. **b** zinc in cartridge brass.

- Construct an empty results table that could be used in an investigation to determine the mass per cent of salt-water samples from four different depths (surface, 5 m, 10 m, 20 m) of Port Phillip Bay. Be sure to include the independent variable and to provide headings for each column.
- Construct a pie chart to display the composition by mass of muntz metal, based on Table 3.2. Refer to the Science how-to section on making a pie chart on page 283.
- You determined that the mass per cent of salt water in Port Phillip Bay for depths at 0, 5, 10 and 20 m is 3.3, 3.4, 3.2 and 3.7 per cent, respectively.
a Fill in your results table with the given data.
b Construct a scatter plot to graph the data, including a trend line. (See step 3 of the 'Processing, modelling and analysing' section of the Science how-to on page 242.)
c Describe the relationship between the variables under investigation.
- Analyse processed data from Question 4 for anomalies and discuss in relation to the rest of the results.

Key idea: Patterns, order and organisation

Evaluate the following statement with reference to patterns, order and organisation of mixtures:
Colloids are homogeneous mixtures because you cannot easily see the difference between the parts of the mixture.

Success criteria

- I can distinguish between different types of mixtures based on observations.
- I can describe the composition of mixtures using percentages.
- I can calculate mass per cent (%m/m) given the mass of the part and the mass of the mixture.

3.5 ▶ Elements, compounds and mixtures in action



Learning intention

At the end of this lesson, I will be able to describe the properties and uses of some common elements, compounds and mixtures.

Key terms

lattice: a three-dimensional structure made of a repeating pattern of atoms or particles

steel: an alloy made of iron and carbon

Investigation 3.5

Comparing the properties of elements, compounds and alloy mixtures, p. 313

Key idea: Patterns, order and organisation

Elements, compounds and mixtures have different properties and are used in many ways in everyday life.

▲ **Figure 3.24:** Oxygen is a versatile and important element, whether in elemental form in the air we breathe or in compound form like in the rocks we climb.

Elements have different properties from their compounds

Carbon forms many compounds with other elements. All living things contain large amounts of carbon. So does crude oil (oil that has not been separated into usable petroleum products), because it is a fossil fuel formed from the remains of once-living things. Crude oil is used for manufacturing petrol, engine oil, candle wax and plastics. Pure carbon can have very different properties from compounds of carbon. For example, diamonds are pure carbon, while the compound carbon monoxide (CO) is a gas that also contains oxygen.

Oxygen also forms many compounds with other elements. One such compound is water (H₂O), which contains hydrogen (H) and oxygen (O) (see Figure 3.25). When oxygen is part of a compound, its properties can vary significantly. For example, the oxygen we breathe (O₂) is a gas at room temperature, while water (which contains oxygen) is a liquid.

The compound silicon dioxide (SiO₂) – made up of silicon (Si) and oxygen (O) – is found in most types of rock. The oxygen we breathe has very different properties from the rocks we climb. Silicon dioxide forms a non-metallic, solid **lattice** of a repeating pattern of atoms, creating a hard, rough texture, making it an ideal type of rock for climbers.

Another compound of oxygen is aluminium oxide (Al₂O₃), which is made up of the elements aluminium and oxygen. This compound forms a similar structure to silicon dioxide, but with a different ratio of atoms that gives a crystalline appearance and shine. ‘Crystalline’ means having the structure and form of a crystal, with well-defined edges and faces. Aluminium oxide is known as ruby or sapphire depending on whether it is red or blue, but their chemical and physical structures are the same.

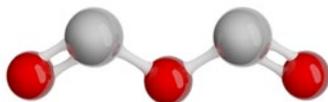
Substances in mixtures retain their own properties

In a mixture, the substances are physically combined, not chemically bonded. This means each substance keeps its own properties.

▼ **Figure 3.25:** Water (H₂O) is a compound of hydrogen and oxygen.



▼ **Figure 3.26:** Aluminium oxide (Al₂O₃) is a compound of oxygen and aluminium.



▼ **Figure 3.27:** Substances in a mixture keep their own properties, allowing magnetic iron filings to be separated from non-magnetic sulfur powder.



3.6 ▶ Representing matter

Learning intention

At the end of this lesson, I will be able to use models and representations to describe and compare elements, compounds and mixtures based on the types and arrangement of their particles.

Key terms

ball-and-stick model: a model that represents atoms as balls and bonds as sticks, making it easy to see how atoms are connected and arranged in space

chemical bond: a force that joins atoms together in a molecule or compound

molecular elements: molecules made up of more than one of the same type of atom

particle model diagram: shows the arrangement and movement of particles in a substance

space-filling model: a model that shows how molecules might appear if magnified

structural formula: a representation of a compound or molecule that shows how atoms are chemically joined to one another

Investigation 3.6

Making a molecular modelling kit, p. 315

Key idea: Patterns, order and organisation

Figure 3.30: This particle model diagram shows particles of a substance in different states.

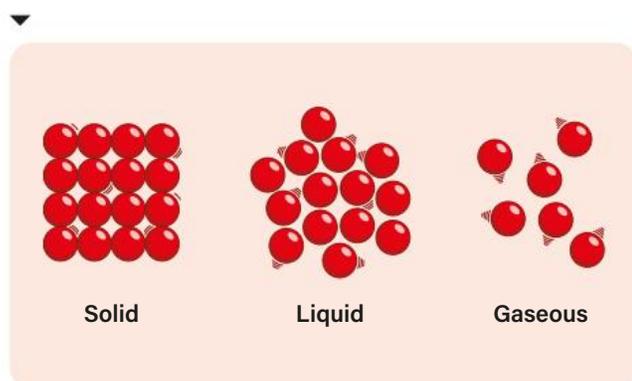


Figure 3.29: Complex molecules like caffeine are often represented using stylised 3D images, generated digitally for visual appeal.

We have learnt that elements can be represented by symbols, compounds by chemical formulas, and mixtures by percentages, but these representations give us little information about shape or structure. This is why various types of models are helpful when representing elements, compounds and mixtures. Models enable us to classify, describe and compare different types of matter, and help us to understand how particles are arranged in a given substance. In this section, we will explore the different models used to represent matter and identify when it is appropriate to use certain models, depending on their purpose and context.

Particle model diagrams can be used to represent the behaviour of matter

A simple and effective way to represent the arrangement and movement of particles under different circumstances is by using a **particle model diagram**. These diagrams use coloured circles or shapes to represent particles in general. For example, when a substance's state of matter changes, particle model diagrams show how the arrangement of particles differs in each state. It is not always obvious if the particles shown are elements or compounds, but this is not important in cases where atoms are not the focus.

Particle models can also help us to compare different mixtures – for example, the differences between elements and compounds, and between homogeneous and heterogeneous mixtures, including solutions, alloys, suspensions and colloids. The diagrams shown in Table 3.3 are especially useful for comparing the behaviour of substances under various conditions. A limitation of particle model diagrams is that they do not usually show the individual types of atoms involved and how they are connected.

Table 3.3: Particle models allow us to compare how atoms are arranged in different substances.

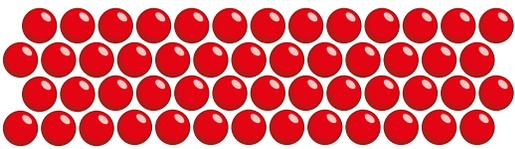
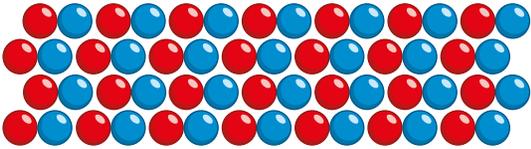
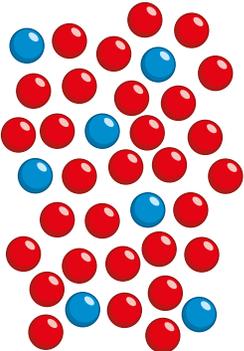
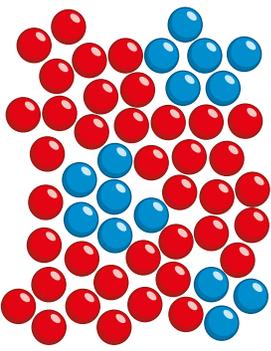
	Particle model diagram	Description of what is represented
Element		<ul style="list-style-type: none"> All atoms are identical.
Compound		<ul style="list-style-type: none"> More than one type of atom is present.

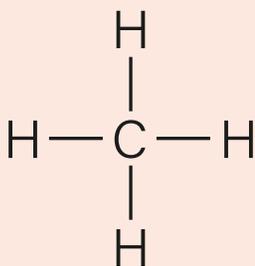
Table 3.4: Particle models allow us to compare how atoms are arranged in different types of mixtures.

Type of mixture		Particle model diagram	Description of what is represented
Homogeneous 	Solution		<ul style="list-style-type: none"> Substance has an even distribution of particles throughout the mixture. Solute particles are dissolved in the solution. Solute particles are so small they are invisible to the naked eye, resulting in a clear solution.
	Alloy		<ul style="list-style-type: none"> Substance has an even distribution of particles throughout the mixture. Metal particles retain their own properties (colour) at the atomic level. Metal particles appear as one colour to the naked eye.
Heterogeneous 	Suspension		<ul style="list-style-type: none"> Solute particles are not dissolved and are visible to the naked eye. Solute particles are large enough that they settle to the bottom of the mixture.
	Colloid		<ul style="list-style-type: none"> Solute particles are not dissolved and are visible to the naked eye. The mixture is cloudy, indicating insoluble particles. Solute particles are small enough that they remain suspended in the mixture for long periods of time.

Structural formulas represent the 2D structure of molecules

A **structural formula** is a two-dimensional (2D) representation that shows how atoms are arranged and **chemically bonded**, or joined together, in a molecule. In these diagrams, atoms are represented by their chemical symbols and lines are used to show the bonds between them. Structural formulas help us to understand the basic shape and connections within a molecule. For example, methane (CH_4) is a carbon atom chemically bonded to four surrounding hydrogen atoms. Figure 3.31 shows the structural formula for methane.

Figure 3.31: The structural formula for methane (CH_4)



Oxygen gas (O_2) and ozone (O_3) are each different forms of **molecular elements** of oxygen, but their chemical formula alone does not show the shape of the molecule or how the atoms are connected. Unless the structural formula is provided, you would not know that the two oxygen atoms in the gas we breathe are connected by a double bond, or that ozone connects three oxygen atoms, bent in a row with a single bond and a double bond.



Figure 3.32: The structural formula for the oxygen gas molecule we breathe (O_2)

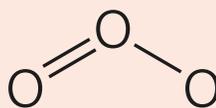


Figure 3.33: The structural formula for the ozone molecule (O_3)

Figure 3.34: This ball-and-stick model shows the 3D arrangement of silicon and oxygen in the crystalline compound silicon dioxide (SiO_2).

Molecular models can be used to represent 3D structures

Molecular models help us to visualise the three-dimensional (3D) shape of molecules and compounds, which cannot be shown easily by structural formulas. **Ball-and-stick models** represent atoms as balls and bonds as sticks, making it easy to see how atoms are connected and arranged in space.

Ball-and-stick models can also be used to represent crystalline lattice structures that have continuous repeating patterns of atoms, rather than a distinct molecule with a specific number of atoms. For example, the compound sodium chloride is not a molecule, because it forms a 3D structure with an undetermined number of alternating sodium and chlorine atoms.

Figure 3.35: In molecular modelling kits, the balls are colour-coded to represent different types of atoms, and sticks are included to represent the chemical bonds that connect the atoms.

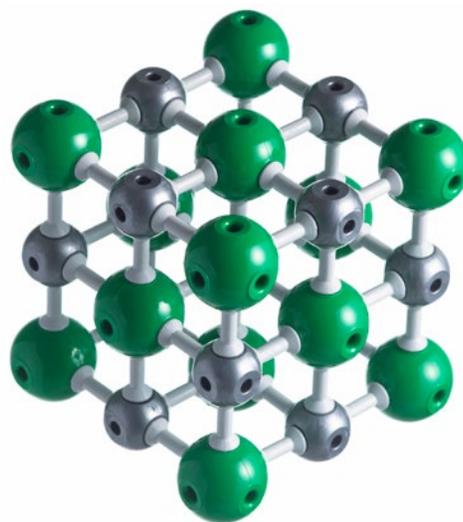
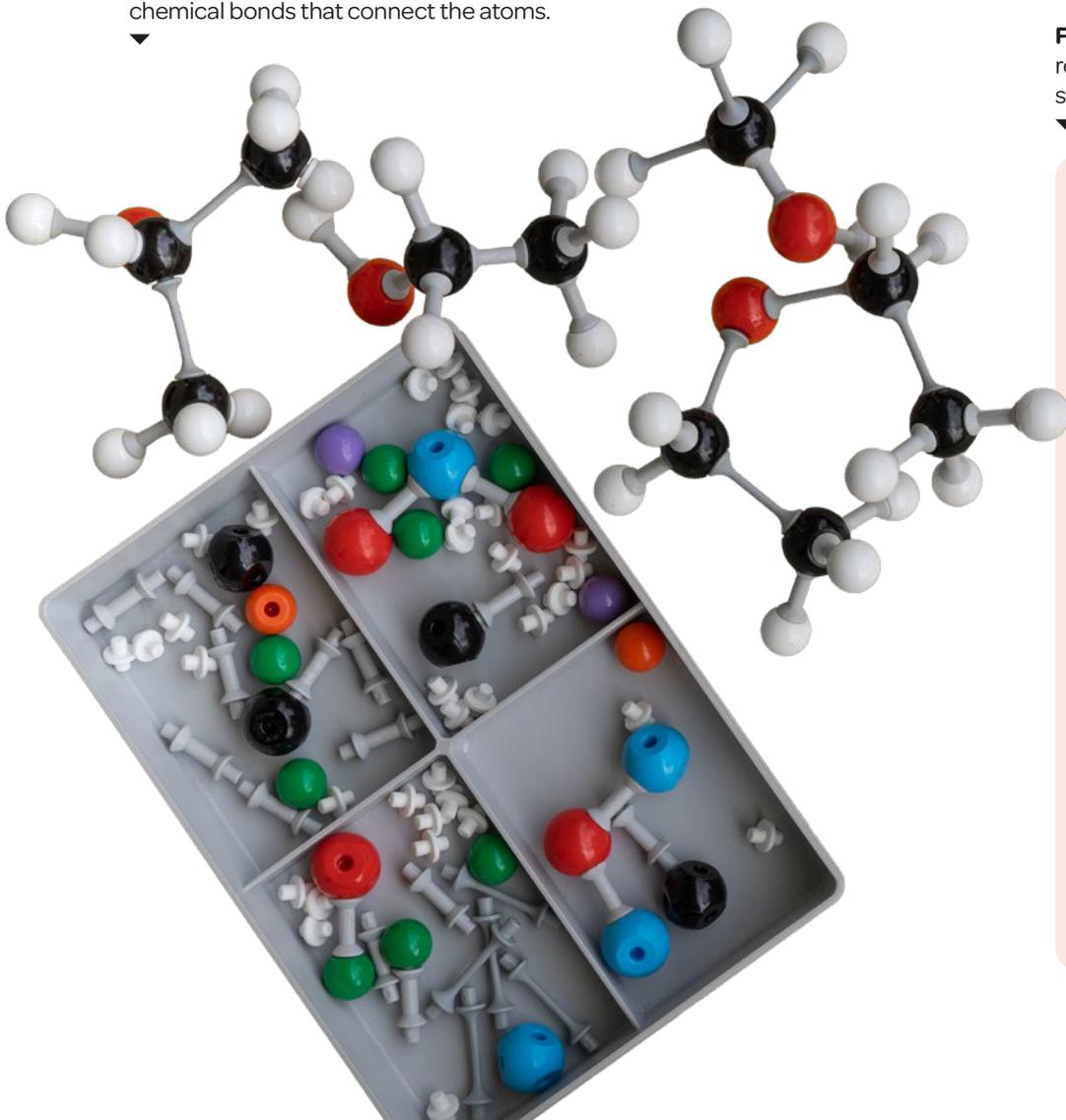


Figure 3.36: This ball-and-stick model represents the 3D lattice structure of sodium chloride.

Space-filling models represent the size and closeness of atoms more realistically, showing how molecules might appear if magnified. Both types of models can be physical (meaning you can hold them in your hands) or virtual (meaning they are generated digitally or on paper). They are especially useful for comparing the shapes of different molecules and visualising how the different types of atoms are connected.

Figure 3.37: Methane's 3D structure is best represented by a ball-and-stick model or a space-filling model.

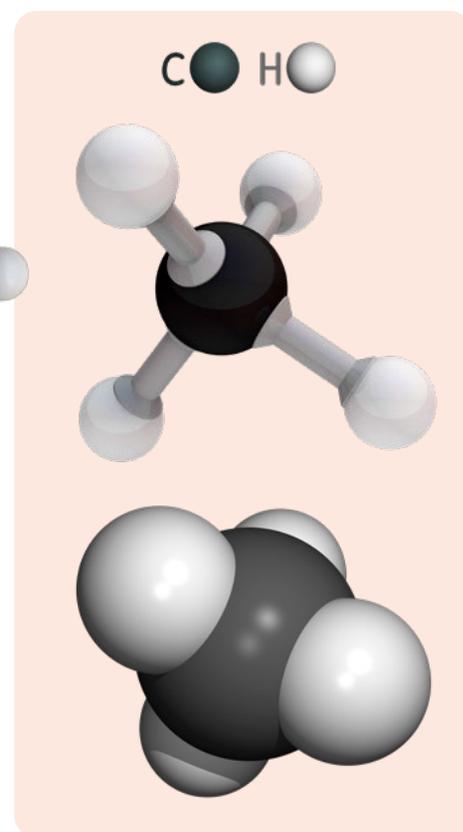
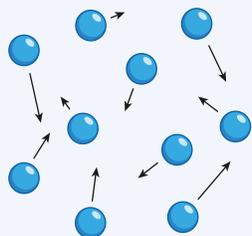


Figure 3.38: Ammonia (NH₃) can be represented in a number of different ways, each serving a particular purpose.

Particle model diagram at room temperature



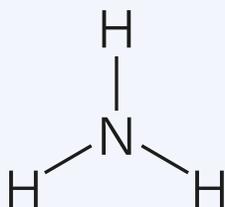
- Shows molecules as a gas at room temperature. Each molecule is shown as an individual particle, even though each particle is made up of four atoms.

Chemical formula



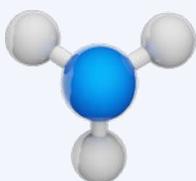
- Shows the ratio of atoms in a molecule.

Structural formula



- Shows the chemical bonds between atoms in a molecule.

Ball-and-stick model



- Shows the shape of the molecule.
- Uses sticks to represent bond angles.

Space-filling model

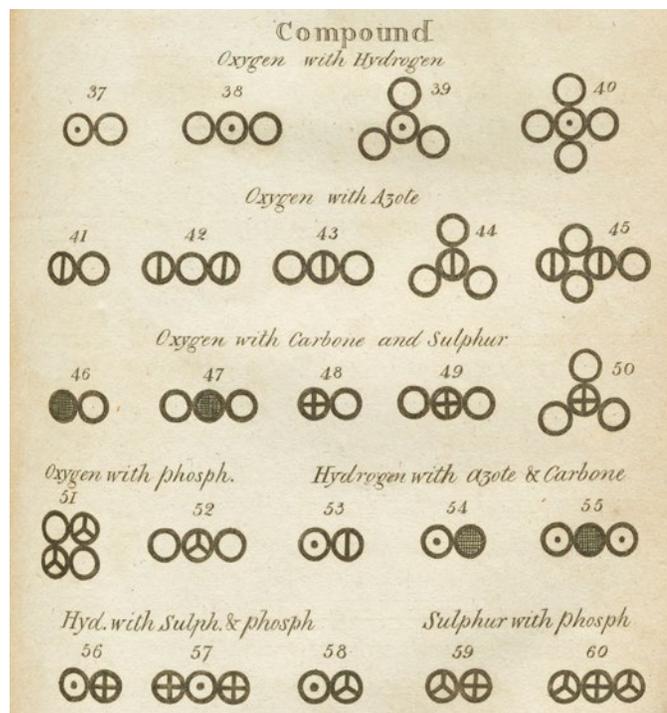


- Shows the shape of the molecule.
- Shows the overlap of atomic boundaries that occurs when bonds are formed.

Different representations give different kinds of information

Each way of representing matter – symbols, formulas, diagrams and models – provides different information about elements and compounds. Chemical symbols and formulas tell us what types of atoms are present and in what ratios. Scientists choose the most suitable representation depending on what they are trying to show – such as composition, structure or behaviour. This makes it easier to compare substances and to explain how matter works at a particle level. Figure 3.38 shows the different ways that ammonia (NH₃) can be represented.

Figure 3.39: John Dalton represented compounds in a way that showed the ratio of types of atoms as well as the connections between them.

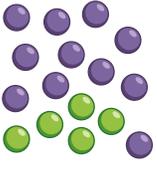
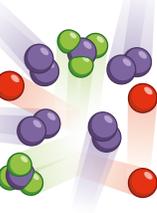


Learning Ladder

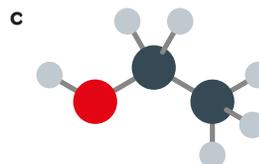
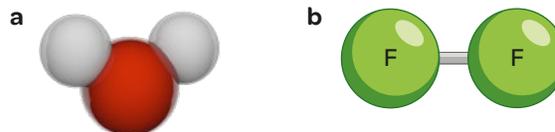
Organising matter

- 1 Complete the sentences below.
- Particle model diagrams do not always show the different _____ that make up a substance.
 - Space-filling models are similar to _____-and-_____ models because they show the 3D shape of molecules.
 - _____ formulas are like chemical _____ because they show the ratio of types of atoms in a substance, but neither of them clearly represents _____.

- 2 Copy and complete the following table to identify each representation. Classify each substance as an element, compound or mixture.

Representation	Type of representation	Type of substance (element, compound or mixture)
		
		
$\text{H}-\text{O}-\text{O}-\text{H}$		
		
		

- 3 For each of the following models, write the chemical formula and the structural formula.



- 4 Propose and explain a situation where each of the following ways to represent substances would be preferred.

- Particle model
- Structural formula
- Molecular model

- 5 Refer to Figure 3.34 to analyse the suitability of silicone dioxide as the chemical foundation for rock structures around the world.

Use and influence of science

- Propose why it might be beneficial to represent molecules using structural formulas.
- Describe examples of virtual representations of chemical substances that you have seen in advertisements.

Processing, modelling and analysing p. 240

- See Figure 3.38.
 - Identify how many ways ammonia (NH_3) can be represented.
 - Propose which way provides the most information about the molecule.
- Construct a display (similar to Figure 3.38) of all the ways the following substances can be represented.
 - Water
 - Carbon dioxide
 - A solution of salt (NaCl) dissolved in water

Key idea: Patterns, order and organisation

Discuss how different models and representations help scientists to identify patterns that exist across different types of matter. Provide examples, including models and diagrams, to support your response.

Success criteria

- I can construct and interpret models and representations of elements, compounds and mixtures.
- I can use models and representations of matter to compare elements, compounds and mixtures.

3.7 ▶ Properties of matter influence their use

Learning intention

At the end of this lesson, I will be able to explain how the properties and availability of some materials – metals, alloys and compounds – influence their uses.

Key terms

bronze: an alloy made of copper and tin

ochre: an earth-based pigment containing iron(III) oxide used for thousands of years by First Nations Peoples for painting, art and ceremony

Investigation 3.7

Modifying metals, p. 317

Key idea: Patterns, order and organisation



▲ **Figure 3.40:** During the Stone Age, humans made and used stone tools.



▲ **Figure 3.41:** Many medical instruments are made from steel.

Since ancient times, humans have used the materials available to them – including elements, compounds and alloys – in a variety of ways. The properties of the materials dictated what tasks they were suited to and how they were used by humans.

The properties of rocks make them useful tools

Recall that most rocks are made primarily of the compound silicon dioxide (SiO_2), which contains the elements silicon and oxygen chemically joined in a repeating three-dimensional pattern.

Humans have been using rocks or stones as tools for thousands of years. This was particularly the case during the Stone Age, as many metals and alloys had not yet been discovered or invented. The early humans who lived in the Stone Age discovered that different types of rocks suited different tasks. For example, obsidian is a rock that breaks into sharp pieces; these pieces were used as arrow tips and scrapers. Very hard rocks with coarse textures – like granite – were used to grind food, and hard rocks with smooth textures were used to make axes.

The properties of bronze make it ideal for making strong weapons

Bronze is an alloy; it is made from two metals: copper and tin. Bronze is much stronger and harder than pure copper. The ancient Sumerians were the first people to make this alloy, in around 3500 BCE. After bronze was discovered, people began making tools and weapons from this material as it is much harder than other materials they had previously used to make these objects (such as pure copper). It is also more resistant to corrosion (wearing away) and is easier to melt and cast into shapes.



▲ **Figure 3.42:** Ancient peoples used bronze to make tools and weapons, including spears.

The properties of steel make it ideal for making medical instruments

Around 400 BCE, metalworkers discovered that adding carbon to iron created a stronger substance than pure iron. Today, this alloy is called steel. Steel is stronger than bronze, harder than iron and lighter than both these substances. Today, steel is used for a wide variety of purposes, including in construction (e.g. the Sydney Harbour Bridge) and to make medical instruments.

The properties of ochre make it ideal for making art

People from many cultures have developed and used dyes and paints obtained from natural sources. A substance called **ochre** is widely used by Aboriginal and Torres Strait Islander Peoples for making art and for ceremonies. Ochre is a naturally occurring substance that is a mixture of clay, sand and a compound called iron(III) oxide. The substance is mixed with water, animal fat, saliva or blood and then painted on rock, weapons, ceremonial objects and skin. Mixing different amounts of the ingredients results in different colours, such as reds, yellows and browns.



Figure 3.43: First Nations Peoples paint rock, weapons and skin with a substance made from ochre.

Learning Ladder

Organising matter

- Complete the sentences below.
 - For thousands of years, people have used their knowledge of the _____ of _____ to decide how to use them.
 - As the properties of different _____ were discovered, tools became more sophisticated.
 - People from many different _____ have developed and used dyes and paints obtained from natural sources.
- Classify the following utensils as elements, compounds or mixtures, and provide a reason for your response.
 - Rocks
 - Copper
 - Bronze
 - Steel
 - Ochre
- Identify the ratio of silicon to oxygen in the compound silicon dioxide.
 - The ratio of iron (Fe) to oxygen (O) in the compound used in ochre is 2:3. Construct the chemical formula to represent iron(III) oxide based on this known ratio.
- Explain the properties of specific types of rocks that enabled them to be used as:
 - arrow tips.
 - grinding tools.
 - axes.
- Propose and analyse the purpose of blood being used alongside ochre by First Nations Peoples. Consider that it is a colloid mixture with many components.

Use and influence of science

- Identify an issue with using copper to make tools and weapons.

- Describe how scientific knowledge about the properties of alloys has affected society.
- Propose and explain an environmental impact of using alloys for weapons and tools instead of rocks.
- Medical instruments must be very clean to avoid infection in patients. Steel is able to resist high temperatures without damaging the metal. Discuss how these facts are related to each other.
- Analyse the following statement in relation to ochre. *First Nations Peoples used the Earth in sophisticated and scientific ways, many of which have informed scientific advances and modern technology.*

Planning and conducting

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- Identify at least five materials and/or pieces of equipment that would be required for you to make your own ochre-based paint.
- Propose and describe things you would do to prevent injury or harm when making paint with the materials identified in Question 1.

Key idea: Patterns, order and organisation

Undertake research to create a list of materials and substances used by First Nations Peoples. Organise your results in a table that outlines the properties of the material and their uses. Examples of materials that could be included are resin, wood, bark, animal parts, minerals/rocks and fibres.

Success criteria

- I can explain how the properties and availability of some materials influence their uses.

3.8 ▶ Key idea: Patterns, order and organisation – organising elements into a periodic table

Learning intention

At the end of this lesson, I will be able to describe how early versions of periodic tables have contributed to the Periodic Table that is universally used today.

Key terms

atomic mass: the mass of an atom of a chemical element

periodic table: a table of elements arranged periodically in a table based on their properties

periodicity: quality of being periodic; the tendency for something to occur repeatedly or in patterns

Key idea: Patterns, order and organisation

As more and more elements were discovered throughout history, scientists needed a way to organise them and to identify patterns in their properties. In the early 1800s, John Dalton began classifying elements by their **atomic mass** (how heavy their atoms were). Over the years, many other scientists also searched for ways to group elements based on their behaviour and characteristics.

In the 1860s, Dmitri Mendeleev built on these earlier ideas and developed a new way to arrange the elements into a **periodic table**. His work marked a turning point in how scientists understood the relationships between different elements.

Different versions of periodic tables have been created by scientists over time. When we use the Periodic Table in this book (written with initial capital letters), we are talking about the modern version that is used around the world today, as shown in Section 3.2.

Dalton produced an early periodic table of 20 elements

As you learnt in Section 3.1, John Dalton proposed his theory that all matter is made up of tiny particles called atoms. In the early 1800s, Dalton began organising the known elements in an attempt to find order among them. He arranged 20 elements into a simple table, based on their atomic mass and some of their basic properties (see Figure 3.44). He also created symbols to represent each element, which helps scientists to communicate with each other more clearly.

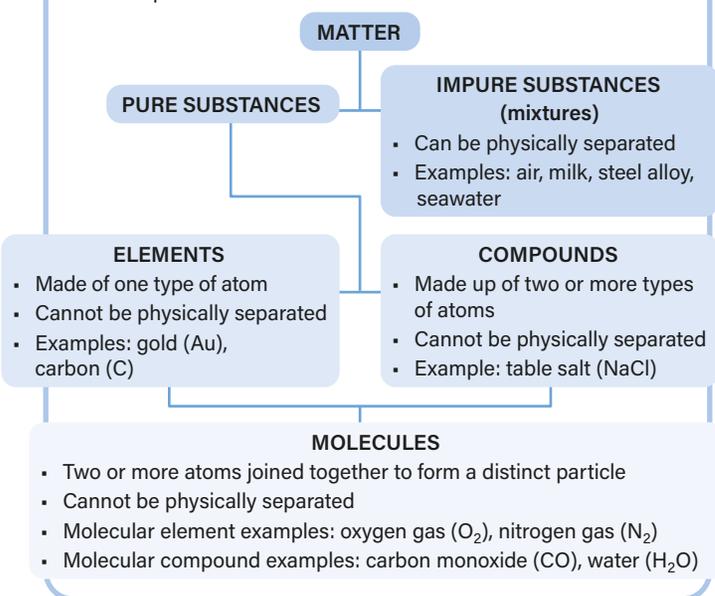
Although Dalton's table was very different from the one we use today, it was an important step towards organising elements in an orderly way. Dalton's work encouraged other scientists to look for patterns in the elements, setting the stage for further discoveries and more sophisticated tables in the years to come.

ELEMENTS	
Hydrogen	Strontian
Nitrogen	Barytes
Carbon	Iron
Oxygen	Zinc
Phosphorus	Copper
Sulphur	Lead
Magnesia	Silver
Limic	Gold
Soda	Platina
Potash	Mercury

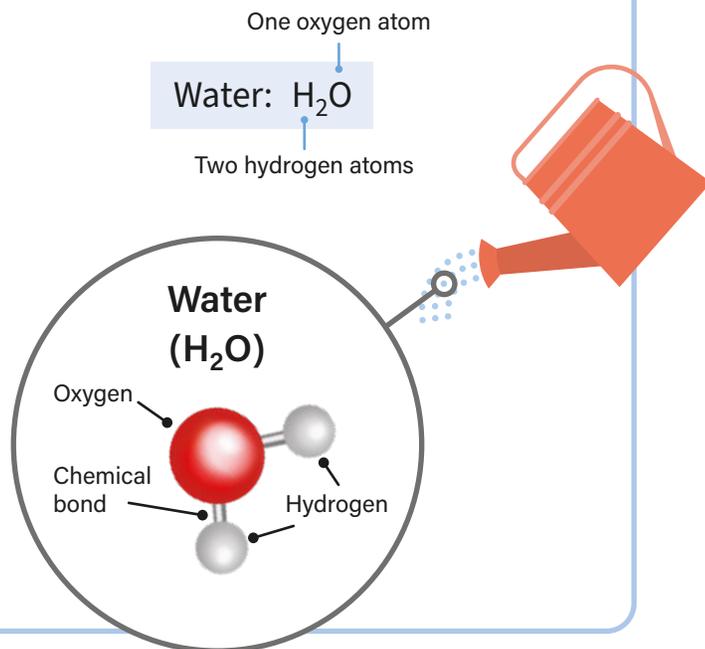
▲ **Figure 3.44:** English scientist John Dalton organised 20 'elements' by their atomic mass into one of the earliest-known versions of a table of elements.

► Summary

- Matter can be classified as pure and impure substances, and further classified as elements, compounds or mixtures.
- The atomic theory of matter can be used to model and explain the difference between elements, compounds and mixtures.



- Compounds and molecules can be represented by their chemical symbol, which uses subscript numbers to show the ratio of elements in the substance. The chemical formula for water is H₂O.



- Elements can generally be classified as metals or non-metals.
- Elements are represented by their chemical symbol and are organised into the Periodic Table.

Atomic number

Chemical symbol

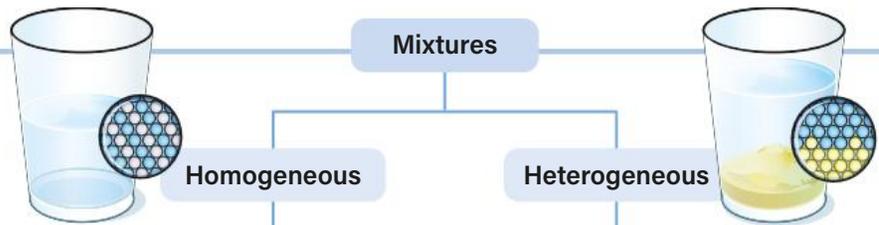
Element name

Metals

Non-metals

1 H Hydrogen																	2 He Helium				
3 Li Lithium	4 Be Beryllium															5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
11 Na Sodium	12 Mg Magnesium															13 Al Aluminium	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
19 K Potassium	20 Ca Calcium	21 Sc Scandium	22 Ti Titanium	23 V Vanadium	24 Cr Chromium	25 Mn Manganese	26 Fe Iron	27 Co Cobalt	28 Ni Nickel	29 Cu Copper	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton				
37 Rb Rubidium	38 Sr Strontium	39 Y Yttrium	40 Zr Zirconium	41 Nb Niobium	42 Mo Molybdenum	43 Tc Technetium	44 Ru Ruthenium	45 Rh Rhodium	46 Pd Palladium	47 Ag Silver	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon				
55 Cs Cesium	56 Ba Barium	57 La Lanthanum	72 Hf Hafnium	73 Ta Tantalum	74 W Tungsten	75 Re Rhenium	76 Os Osmium	77 Ir Iridium	78 Pt Platinum	79 Au Gold	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon				
87 Fr Francium	88 Ra Radium	89 Ac Actinium	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson				
		58 Ce Cerium	59 Pr Praseodymium	60 Nd Neodymium	61 Pm Promethium	62 Sm Samarium	63 Eu Europium	64 Gd Gadolinium	65 Tb Terbium	66 Dy Dysprosium	67 Ho Holmium	68 Er Erbium	69 Tm Thulium	70 Yb Ytterbium	71 Lu Lutetium						
		90 Th Thorium	91 Pa Protactinium	92 U Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium						

metals
 non-metals
 metalloids



- Mixtures can be classified as homogeneous or heterogeneous.
- Mixtures do not have fixed ratios of elements, so their composition can be represented by percentages.

Solutions:

- Salt water
- Lemonade
- Tea

Alloys:

- Steel
- Bronze
- Brass

Suspensions:

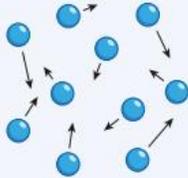
- Muddy water
- Pulpy orange juice
- Plunger coffee

Colloids:

- Milk
- Fog or clouds
- Smoke

- Elements, compounds and mixtures can be represented using diagrams, chemical formulas, and two-dimensional and three-dimensional models.

Particle model diagram at room temperature



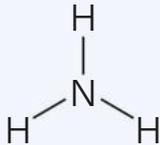
- Shows molecules as a gas at room temperature. Each molecule is shown as an individual particle, even though each particle is made up of four atoms.

Chemical formula



- Shows the ratio of atoms in a molecule.

Structural formula



- Shows the chemical bonds between atoms in a molecule.

Ball-and-stick model



- Shows the shape of the molecule.
- Uses sticks to represent bond angles.

Space-filling model



- Shows the shape of the molecule.
- Shows the overlap of atomic boundaries that occurs when bonds are formed.

- The properties of matter influence how they are used.



Key idea:

Patterns, order and organisation

- Early versions of the periodic table have contributed to the order and organisation of the Periodic Table that is used universally today.

ELEMENTS			
Hydrogen 1	Strontian 46		
Nitrogen 5	Barytes 68		
Carbon 6	Iron 50		
Oxygen 7	Zinc 56		
Phosphorus 9	Copper 56		
Sulphur 13	Lead 90		
Magnesia 20	Silver 190		
Lime 24	Gold 190		
Soda 28	Platina 190		
Potash 42	Mercury 167		



Masterclass

Steps in progression

1

2

Science understanding	Organising matter	<p>a Identify the atomic number for mercury using the Periodic Table.</p> <p>b Identify how many protons an atom of mercury contains.</p>	Describe the property of mercury that makes it unique as compared to other elements of the Periodic Table.
Science as a human endeavour	Nature and development of science	Identify how amalgam silver alloy addressed dental hygiene problems.	<p>a Propose three professionals who may have worked together to develop amalgam silver alloy to be used in the dental industry.</p> <p>b Describe the importance of collaboration in this scenario.</p>
	Use and influence of science	Propose whether mercury in ecosystems, building up inside fish, is an ethical, environmental, economic or social issue. Provide a reason.	In the Hanover Poisoning case, the stranger on the street must have known that mercury is toxic. Describe how his knowledge of science affected society.
Science inquiry	Planning and conducting	Identify the equipment that would be required to make amalgam silver alloy, to measure the correct amounts of each metal, and to melt them together into a mixture.	<p>a Identify four hazards related to making amalgam in the laboratory.</p> <p>b Describe ways to minimise the risks associated with each hazard.</p>
	Processing, modelling and analysing	Refer to Figure 3.48. Identify the percentage of each of the following elements in amalgam dental fillings: mercury, silver, tin.	<p>a Construct a table to display the information in Figure 3.48.</p> <p>b Construct a pie chart to represent the information in Figure 3.48.</p>

When elements become deadly

Chemical elements are typically used for beneficial purposes such as medicine, technology and energy. However, some elements can be hazardous when misused or mishandled. For example, mercury (Hg) is toxic if ingested and can be harmful to ecosystems. Unlike any other metal, mercury is a liquid at room temperature, which is why it was commonly used in thermometers and amalgam (silver alloy) dental fillings (Figures 3.48 and 3.49) before scientists understood the dangers of this element.

One instance of mercury being deliberately misused is in the Hanover Poisoning case. In 2011, a man mysteriously became terminally ill after being poked by a stranger's umbrella on the street. Through chemical analysis and processing, it was determined that the man had been poisoned when he was stabbed by the umbrella containing a mercury-filled needle.

Figure 3.48: The composition of amalgam (silver alloy) dental fillings

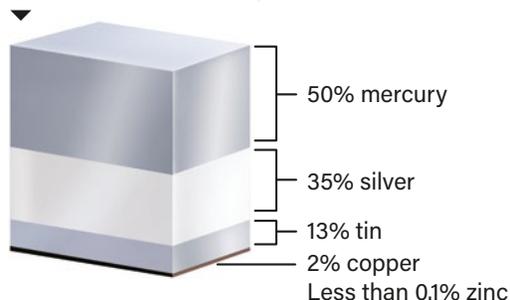


Figure 3.49: Amalgam (silver alloy) dental fillings

Demonstrate your understanding

3

Figure 3.48 shows the composition of amalgam silver alloy. Construct a diagram of amalgam at the atomic level.
Hint: Use a 10 × 10 grid of particles.

Propose examples of evidence that would have led to the understanding that mercury is toxic to people and harmful to ecosystems.

Explain how members of the general public having access to toxic elements such as mercury has ethical impacts.

Identify the independent, dependent and controlled variables when investigating properties of different types of alloys to be used as dental fillings.

- a Construct a column graph to visually display the information in Figure 3.48.
- b Identify the type of graph displayed in Figure 3.50.

4

Propose how mercury's unique properties enabled it to be used in thermometers to indicate temperature.

Discuss how mercury being identified as 'toxic' changed the way it was used in society, with reference to specific examples.

Discuss how restricting the use of hazardous substances such as mercury has helped to minimise socio-scientific issues.

- a Construct a results table to record the properties of three types of alloys: melting temperature, solubility, malleability, reactivity.
- b Propose digital tools required to collect data.

Explain the relationship between variables (mercury levels and a pregnant woman's age) displayed by the trendline in Figure 3.50.

5

- a Investigate how mercury interacts with other metals.
- b Discuss how this interaction made mercury ideal for amalgams.

Analyse the following statement:
Most people with amalgam fillings do not have any issues, so there is nothing wrong with continuing to use it in the dental industry.

Analyse the following statement:
Amalgam is called 'silver alloy' because it sounds more prestigious than 'mercury alloy', even though the mass per cent of mercury is higher than silver in the alloy.

Design a step-by-step method for a reproducible investigation that includes safety and ethical considerations. Use step 1 or step 4 as the basis of your investigation.

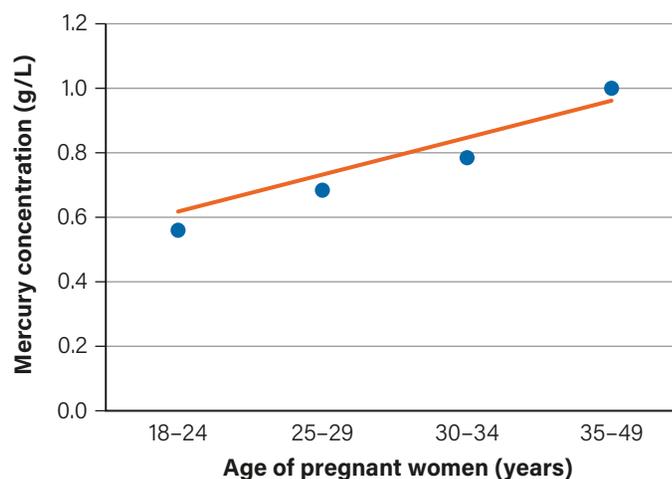
Evaluate the trend in the data in Figure 3.50, discussing any anomalies and/or links to scientific knowledge related to amalgam fillings or mercury in the environment.

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Mercury can accumulate in our bodies slowly over time, particularly from eating fish that have high levels of mercury. Unborn babies are particularly sensitive to the effects of mercury. To educate expectant mothers about the risks of mercury, a study looked at the levels of mercury in pregnant women in the United States. The age of the women was one of the factors that was analysed (see Figure 3.50). The results of the study were used to educate the general population about mercury's risks.

Understanding the dual nature of elements highlights the importance of responsible handling and sustainable practices in harnessing their potential benefits, as well as being able to identify and address circumstances when elements become a threat to health and the environment.



▲ **Figure 3.50:** The mean blood mercury levels in pregnant women aged 18–49 by age group in the United States, 2003–08

4.0 Chemical change

Chemical changes are all around us. Some are dramatic, like fireworks or explosions, while others happen slowly and quietly, like when baking cupcakes or when your body digests food. But what makes a chemical change different from a physical one? Certain clues can help us tell the difference, such as colour changes, temperature changes, bubbles of gas, or new solids forming. In this chapter, you will explore how to recognise these signs and learn about the fascinating ways substances can change.



Learning Ladder

The Learning Ladder for each chapter maps the Science Understanding, Science as a Human Endeavour and Science Inquiry strands that will be covered. Each ladder has five levels of progression, called steps. To climb the ladders, you need to develop fluency at each step. This will help you develop the ability to complete tasks that are more complex.

5	I can analyse models that represent physical and chemical change	I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations
4	I can compare physical and chemical changes with reference to the properties of substances	I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues
3	I can explain physical and chemical changes with reference to the rearrangement of atoms	I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances
2	I can distinguish between physical and chemical changes based on observations	I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society
1	I can make observations during a chemical or physical change	I can recognise scientific problems and solutions	I can identify socio-scientific issues
Steps in progression	Chemical science: Chemical change	Nature and development of science	Use and influence of science
	Science understanding	Science as a human endeavour	



▲ **Figure 4.1:** From baking these cupcakes to lighting the sparklers, even to eating them – chemical changes are taking place all the time.

I can design and conduct reproducible investigations that consider safety, ethical and procedural factors	I can evaluate conclusions and claims with reference to conflicting evidence and unanswered questions	5
I can generate and record data with precision, using digital tools as appropriate	I can create evidence-based arguments to justify conclusions or evaluate claims	4
I can distinguish between variables to be changed, measured and controlled in an investigation	I can use science-based explanations to support investigation findings	3
I can describe ways to minimise risks for a range of investigations	I can describe different types of errors in an investigation method	2
I can identify and select appropriate equipment for scientific investigations	I can identify errors and assumptions in an investigation	1
Planning and conducting	Evaluating	
Science inquiry		Steps in progression

4.1 ► Physical and chemical change

Learning intention

At the end of this lesson, I will be able to:

- describe physical and chemical changes
- distinguish between physical and chemical change by observing indicators of change.

Key terms

chemical change: a change in properties, so that a new substance is formed

physical change: a change in appearance, with no new substance formed

property: characteristic of a substance that can be observed

reversible: can be changed back to its previous state

Investigation 4.1

Observing physical and chemical changes, p. 318

Key idea: Matter and energy

With a *physical* change, no new substance is formed and the process can be reversed. A *chemical* change produces a new substance and the process is not reversible.

Physical changes do not make new substances

When a substance undergoes a **physical change**, its **properties** do not change. A change of state – such as when water changes from solid (ice) to liquid (water) to gas (steam) – is a physical change. All three states still consist of water molecules (H_2O).

Physical changes are **reversible**. Wax can be heated and melted, and then cooled and solidified; it looks the same as before it was melted. Other examples of physical changes are paper being cut, water evaporating, a ruler breaking and sugar dissolving in water.

▼ **Figure 4.2:** Paint undergoes a physical change when it dries.



Chemical changes make new substances

A **chemical change** happens when a chemical reaction causes the atoms in a substance to rearrange and form a new substance.

Evidence of a chemical change includes:

- there is a change in colour
- gas is produced (bubbles)
- a new substance forms/appears
- there is a temperature change (it heats up or cools down)
- light is observed
- a precipitate (solid particles in solution) forms.

Chemical changes are not easily reversible.

For example, you cannot uncook a pancake so that it returns to being batter. Other examples of chemical changes are wood being burnt, a banana rotting, iron rusting and cookies baking.

A reaction can include both physical and chemical changes

It is not always easy to distinguish a physical change from a chemical change. An apparent colour change can sometimes result from a physical change; for example, white snow melts to colourless water,

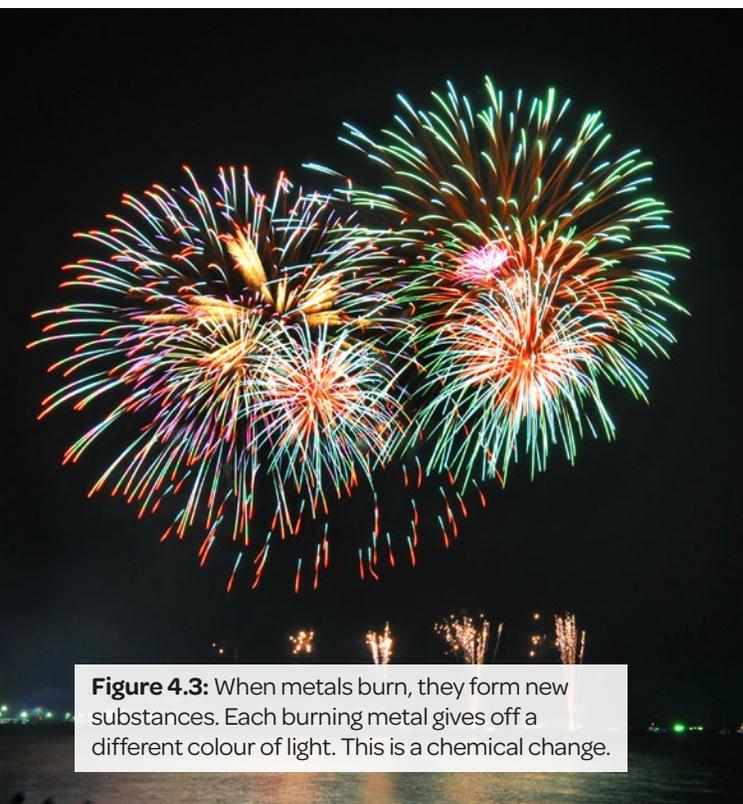


Figure 4.3: When metals burn, they form new substances. Each burning metal gives off a different colour of light. This is a chemical change.

and blue and red paint mixed together look purple. However, a single snowflake would be colourless, and the paint mixture up close would show both red and blue particles (not purple). No new substances have been formed.

Similarly, the production of a gas is not always a sign of a chemical change. When water is boiled, bubbles form, indicating a change of state. It may be necessary to make several observations, not just one, to distinguish correctly between physical and chemical changes.

Figure 4.4: The sugar in the top pan is melting, which is a physical change because no new substances are formed. The sugar in the bottom pan has been heated more, and some has chemically changed into a new substance: caramel.



Learning Ladder

Chemical change

- 1 Identify four observations that might indicate a chemical change is taking place.
- 2 Classify the following as physical or chemical changes. Provide reasons.
 - a Ice melting
 - b A steak cooking on a barbecue
 - c Paper burning
 - d Chocolate powder mixing into milk
- 3 Explain how, when water changes from a solid to a liquid to a gas, these are *not* examples of chemical changes.

Nature and development of science

Being unable to distinguish between physical and chemical changes could be considered a scientific problem.

- 1 Identify how scientists have addressed this problem.
- 2 Propose why being able to tell the difference between physical and chemical changes may be important for professionals other than chemists. Provide examples.

Planning and conducting

p. 236

- 1 Propose equipment that might be used to carry out and observe the following indicators of change.
 - a Two colourless solutions turn pink when they are combined.
 - b A flame is inserted into a reaction vessel and makes a loud popping sound.
 - c A tablet is dropped into a solution. You suspect that a gas forms, but you cannot see any bubbles.

- 2
 - a Identify any hazards associated with each of the tests carried out in Question 1.
 - b Describe how you would minimise each hazard.
- 3 Imagine that the test in Question 1c was being investigated further.
 - a Propose what the independent variable could be.
 - b Identify the dependent variable, based on your response to part a of this question.
 - c Describe how you would control three other variables.
- 4 Explain how you would generate and record precise volumes of gas for the investigation from Question 3. Include a labelled sketch of the equipment set-up and/or describe any digital tools that would be required.
- 5 Design a step-by-step method that a classmate could use to carry out a reproducible investigation (from Questions 3 and 4), including safety, ethical and procedural considerations.

Key idea: Matter and energy

Fireworks use chemical reactions to create new substances and release energy that produces coloured light. Research how matter changes and how energy causes these colour effects.

Success criteria

- I can explain the difference between a physical change and a chemical change.
- I can identify evidence for a chemical change and make links to common examples.

4.2 ▶ Comparing physical and chemical change

Learning intention

At the end of this lesson I will be able to compare physical and chemical changes in terms of the arrangement of particles.

Key terms

electrolysis: passing electricity through a substance to break it up

model: a simplified way of explaining something complex and real based on evidence

molecular formula: an expression of the number and types of atoms in a single molecule of a compound

molecule: two or more atoms chemically bonded together; the smallest unit of a chemical compound

particle theory: all matter is made up of tiny particles; a model used to explain the properties of solids, liquids and gases based on the arrangement and movement of particles

Investigation 4.2

Burning steel wool, p. 320

Key idea: Matter and energy

Now that you know how physical and chemical changes differ, it is time to look at how these changes take place. Like a scientist, you can use a **model** to understand and explain your observations, because the particles in chemical reactions are too small to see.

The particle theory models the behaviour of matter

There are five main ideas in the **particle theory**. This model is helpful to remember as you study chemical reactions:

- 1 All matter is made up of tiny particles.
- 2 All the particles are constantly moving.
- 3 Forces of attraction hold the particles together.
- 4 The further apart the particles are, the weaker the forces of attraction.
- 5 Particles at higher temperatures move faster and with more energy than those at lower temperatures.

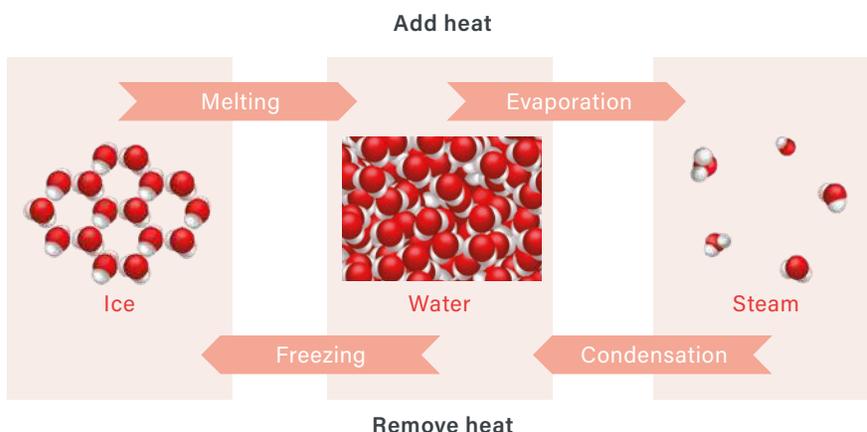
Particles do not change during a physical change

In a physical change, no new products form and the reaction is generally reversible. There is no change to the make-up of atoms or **molecules** of the substance.

You can easily change the state of water by freezing, melting or boiling it. The water molecules stay the same each time, whether the water is a solid (ice), liquid (water) or gas (steam). The molecules will move at a faster or slower rate depending on their state, but they do not stop being water molecules (H_2O).



Figure 4.5: Particles exist all around us as solids, liquids and gases.



▲ Figure 4.6: Water molecules can exist as a solid, a liquid or a gas.

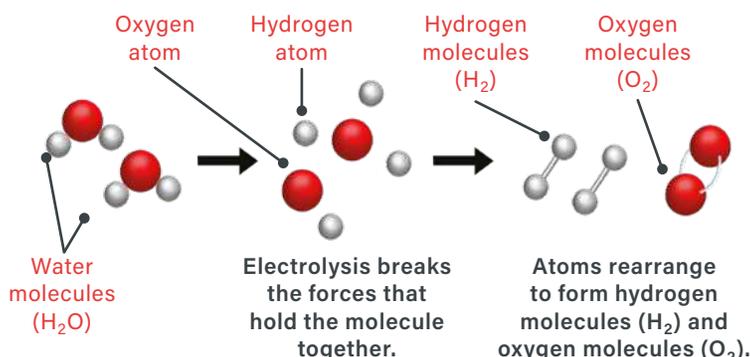
Particles change during a chemical change

In a chemical change, new substances are formed and the reaction is generally not reversible. The particles at the beginning of the reaction are not the same as those at the end. As a reaction happens, the forces that hold atoms together are broken and reformed, joining atoms together in ways that are different from how they started. In other words, atoms in a chemical reaction are rearranged to form new molecules or compounds of new substances.

Water molecules are made up of two hydrogen atoms and one oxygen atom, so the **molecular formula** of water is H_2O . It is not easy to break apart water molecules, but it can be done using **electrolysis**. This process involves passing electricity through the molecules.

The electrical energy breaks the strong bonds holding the oxygen and hydrogen atoms together. The atoms of the water molecules then rearrange and combine to form hydrogen gas (H_2) and oxygen gas (O_2), which are the new substances formed as a result of this chemical reaction.

▼ **Figure 4.7:** The forces holding water molecules together break when electrical energy passes through them. Oxygen and hydrogen gases are formed.



Learning Ladder

Chemical change

- a** Complete the sentences below.
Physical changes are _____, and no new _____ are produced. Chemical changes are _____ . In a chemical change, _____ substances are _____ .
- b** Refer to Figure 4.7. Identify how the atoms of water molecules change to form new substances.
- Compare a physical change to a chemical change, making reference to particle theory.
- Explain how the particle theory model used in Figure 4.6 represents water undergoing physical changes rather than chemical changes.
- Explain, using particle theory, how an instant ice pack becoming ice cold when bent represents a chemical change.

Nature and development of science

- Identify the model that explains the properties and behaviours of substances.
- Propose why graphic designers and chemists may collaborate to explain particle theory.
- Explain how the fact that a water molecule is a single particle but is made up of three atoms changed the model used to represent it.
- Conduct a search to determine how particle theory models have changed over time. Construct an annotated timeline to represent this development.

- Analyse the following statement with reference to particle theory.
Scientists disagree on what goes on with atoms at the particle level. This makes it difficult to develop a model that is general, yet specific enough to suit everyone's beliefs.

Evaluating

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- Identify an assumption you would make when observing a change you are told is physical, not chemical.
- When a red solution is mixed with a yellow solution, the resulting solution is orange. The observer incorrectly declares this to be a chemical change because they observe a new colour. Identify and describe the error they have made.
- Explain, with reference to particle theory, how a new colour can be observed, yet no chemical change has taken place. Justify how a new colour is observed.

Key idea: Matter and energy

Consider the physical change of water from liquid to gas. Now consider the chemical change of water when it breaks down to form hydrogen and oxygen. Compare the differences in terms of energy for the physical changes in water and the chemical changes in water.

Success criteria

- I can use the particle theory model to compare and contrast physical and chemical changes.

4.3 ▶ Representing chemical change

Figure 4.8: When wood is burned in a fireplace, a combustion reaction occurs. Heat rearranges the atoms in the wood and oxygen to form ash, carbon dioxide and water.

Learning intention

At the end of this lesson, I will be able to:

- describe a chemical reaction in terms of reactants and products
- recognise the law of conservation of mass.

Key terms

chemical reaction: a process in which one or more substances are changed to form new substances

conservation of mass: the scientific law that states that mass cannot be created or destroyed but can be arranged in different forms

precipitate: a solid that forms in a solution

product: a substance formed in a chemical reaction

reactant: a substance that undergoes a chemical change

word equation: a representation of a chemical change in words

Investigation 4.3

Law of conservation of mass, p. 321

Key idea: Matter and energy



Chemical reactions might seem mysterious at first, but they actually follow clear, predictable rules. Scientists have discovered that these reactions happen in orderly ways, and by understanding the patterns involved, we can describe and predict chemical changes more easily.

In this section, you will learn how mass is always conserved in a chemical reaction – even when substances seem to disappear or transform. You will also explore how word equations can be used to represent these changes in a simple yet scientific way. Learning to represent reactions accurately helps chemists communicate their ideas and make sense of what is happening on the atomic level.

Conservation of mass

During a chemical reaction, the atoms on the starting substances, called the **reactants**, are rearranged to form new substances, known as the **products**. Although the substances change and new products are formed, no atoms are created or destroyed in the process. This means the number and type of atoms stay the same before and after the reaction; they are simply reorganised into new combinations. Because the atoms are all still there, the total mass stays constant. This important idea is known as the law of **conservation of mass**.

◀ **Figure 4.9:** The same number of atoms are present before and after a reaction occurs.

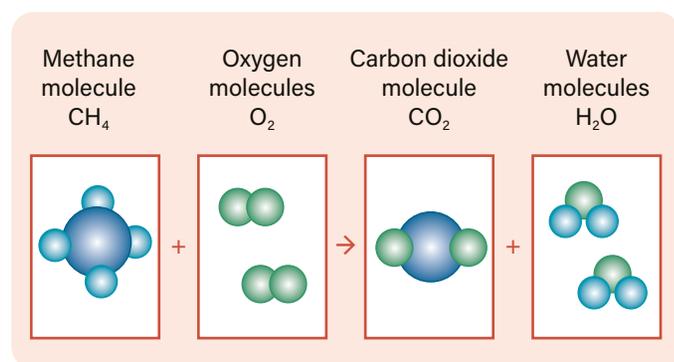


For example, if you start with 10 grams of reactants, you must end up with 10 grams of products. Even if a gas is produced or a solid seems to disappear, the atoms are still present somewhere. They may have changed form or moved, but they have not vanished altogether. Scientists use this principle to help them understand and describe chemical reactions accurately. Simple equations can be used to clearly show how the reactants form new products, while keeping track of the total mass involved.

A chemical reaction is a rearrangement of atoms between substances

A **chemical reaction** occurs when two substances combine in such a way that the atoms rearrange themselves.

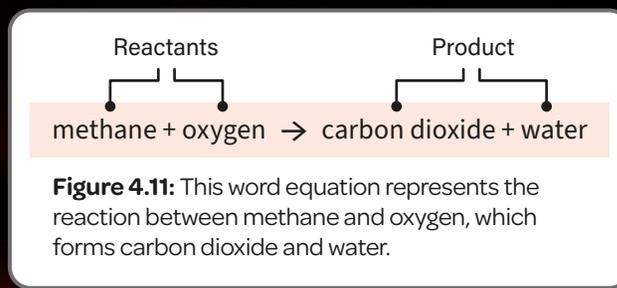
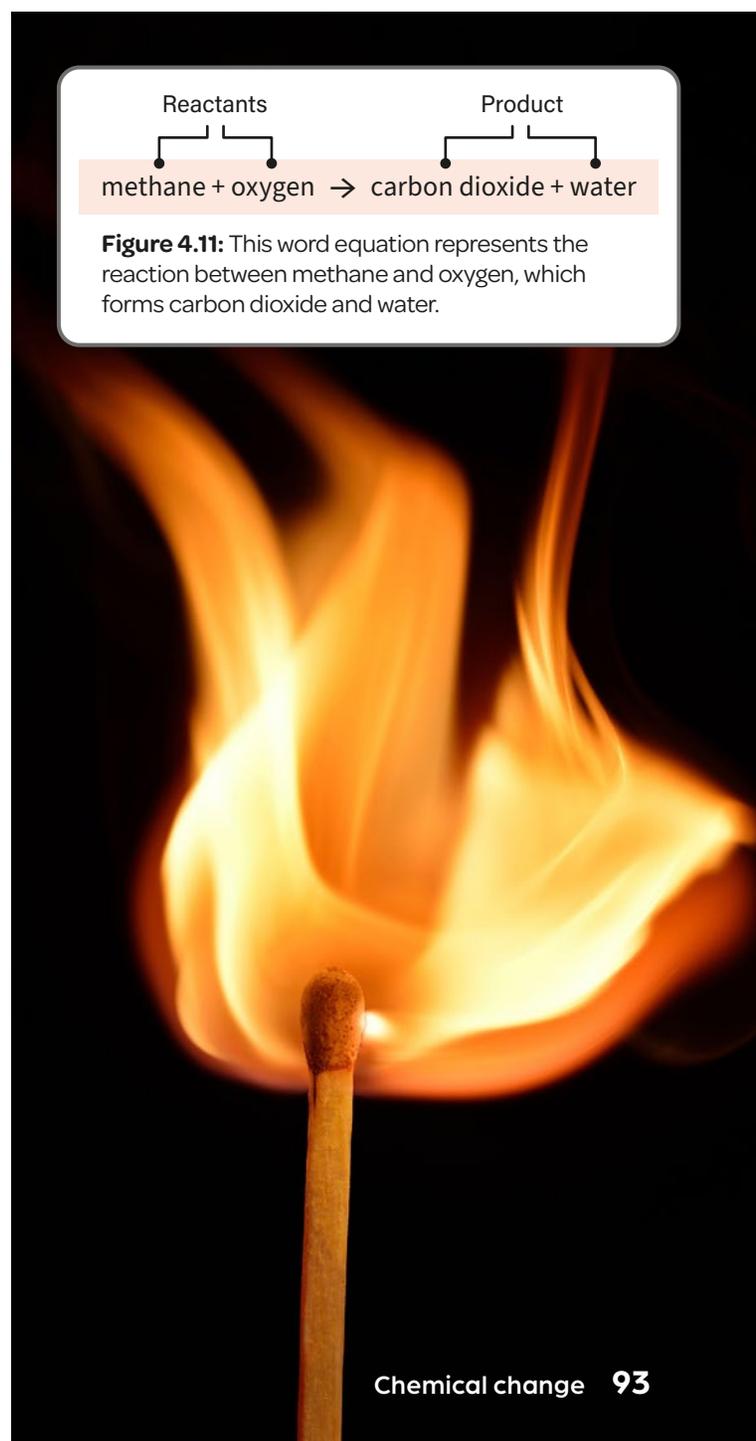
Consider methane: the formula for methane is CH_4 because each molecule of methane contains one carbon atom and four hydrogen atoms. Methane is a fuel that can combust, or burn, with oxygen by adding some energy to get the reaction going. This will cause the hydrogen atoms to break away from the carbon atom and the oxygen molecules to split apart into individual atoms; they then recombine into carbon dioxide and water molecules. You can see in Figure 4.10 that mass is conserved, even though new substances are formed. There are the same number of carbon, hydrogen and oxygen atoms both before and after the reaction – they are just connected to each other differently.



▲ **Figure 4.10:** Methane (CH_4) and oxygen (O_2) molecules split apart and recombine to form carbon dioxide (CO_2) and water (H_2O) molecules.

Word equations can represent chemical reactions

In the reaction in Figure 4.11, the methane and oxygen gases are the initial substances before the reaction: the reactants. Carbon dioxide and water are the new substances formed in the reaction: the products. We can represent this process as a **word equation**. The arrow (\rightarrow) represents the reaction. The reactants are always on the left of the arrow with plus (+) signs between each reactant to indicate that they are 'added' together. The products are always on the right of (after) the arrow, indicating that the reaction has taken place.



Sometimes, the law of conservation of mass might not make sense. Think about a piece of wood burning in a fireplace. The wood is undergoing a chemical reaction known as combustion. After the reaction has finished, the ash left over is much lighter than the original wood. This is because the ash is not the only product of the reaction: carbon dioxide and water are formed, but they have drifted away as gases. If we were to weigh all of the ash, carbon dioxide and water, they would be equal to the mass of the original block of wood and oxygen that reacted.

Using word equations helps to remind us of all the substances involved, before and after a reaction. Figure 4.12 shows that even though a **precipitate**, or solid, substance appears when two clear solutions are mixed together, the mass stays the same. A word equation can be written to represent this reaction.

Figure 4.12: If a reaction occurs in a sealed container, the mass will not change, even if new products are formed.

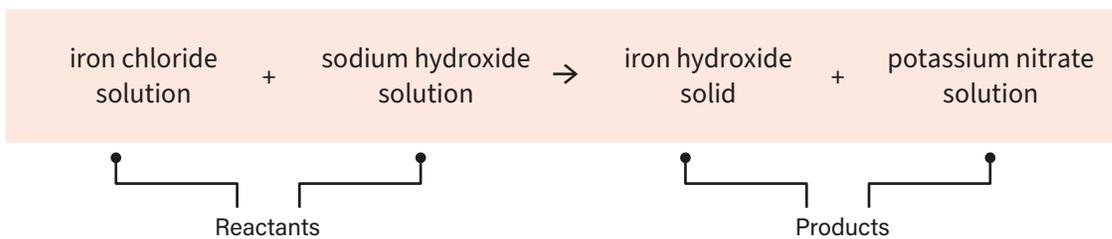
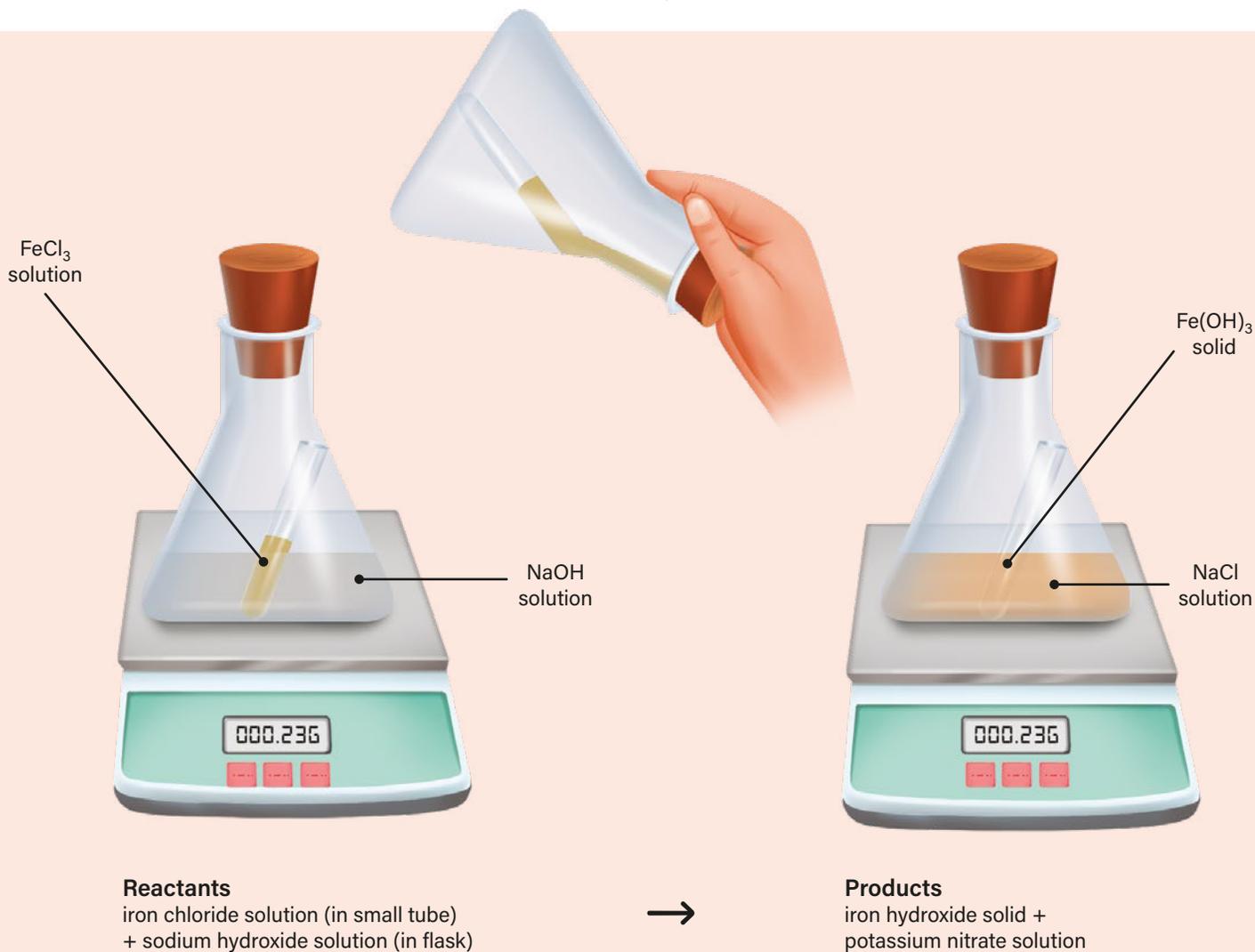




Figure 4.13: Precipitation reactions are a fun way to observe chemical change, as new solid substances (precipitates) form when two clear solutions are mixed. Although a solid appears, no mass is lost or gained. The reaction demonstrates the law of conservation of mass, where all atoms are still present, just rearranged into new substances.

Learning Ladder

Chemical change

- 1 Identify the reactants and products in the following word equations.
 - a zinc + hydrochloric acid → zinc chloride + hydrogen gas
 - b oxygen gas + magnesium → magnesium oxide
 - c hydrogen peroxide → oxygen gas + hydrogen gas
- 2 Propose why an arrow (→) is used in chemical equations, and not an equals (=) sign.
- 3 Write a word equation for photosynthesis, where carbon dioxide and water combine to form glucose and oxygen gas.
- 4 Explain why dissolving salt in water is *not* an example of a chemical reaction.
- 5 The flammable substance on a sparkler stick burns in air. The stick after the sparkler has gone out is lighter than the original stick. Outline what happens to the substance on the stick, making reference to the law of conservation of mass.

Nature and development of science

- 1 Complete the sentence below.

Using _____ has allowed scientists to _____ the changes that take place when _____ (physical/chemical) reactions occur.
- 2 Describe why it is important for scientists all over the world to use an arrow to represent a chemical change, rather than having different scientists using different symbols.
- 3 Carbon dioxide is formed when methane fuel burns, but sometimes black soot (carbon) forms as well. Describe why this evidence is important when writing a word equation for the combustion of methane.
- 4 Use the internet to research and discuss how representations of chemical change have developed over time.

Planning and conducting

p. 236

You are conducting an experiment to support the law of conservation of mass by weighing substances before and after a chemical change.

- 1
 - a Identify the purpose of having a stopper on the reaction flask.
 - b Propose how the word equation of the chemical reaction in the experiment could be used to gather materials to carry out the investigation.
- 2
 - a Propose three ways to minimise the risk associated with glassware used in the investigation.
 - b Describe what you would do if you:
 - i broke a flask during the investigation.
 - ii cut your finger on a piece of broken glass.
- 3 You conduct the investigation with a series of different types of chemical reactions so you have data to compare. Identify the:
 - a independent variable.
 - b dependent variable.
 - c variables that should be controlled, and describe how they should be controlled.
- 4 Explain how the dependent variable will be measured, including the equipment and technique required, as well as the units and precise values that will be generated.

Hint: How many decimals will be recorded?
- 5
 - a Design a step-by-step method that a classmate could use to carry out this investigation safely and ethically.
 - b Have a classmate read your method. Discuss with them any procedural factors that require clarification or modifications, and adapt your method accordingly.

Key idea: Matter and energy

Discuss the importance of being able to use word equations to represent how matter can change into new substances by undergoing chemical change.

Success criteria

- I can identify the reactants and products in a chemical reaction.
- I can use word equations to represent chemical change.

4.4 ▶ First Nations Peoples' use of physical and chemical change

Learning intention

At the end of this lesson, I will be able to describe how First Nations Peoples utilise physical and chemical changes in a variety of ways.

Key terms

antiseptic: a substance that kills or stops the growth of germs such as bacteria, viruses and fungi

cultural burning: the controlled use of fire by First Nations Peoples to care for Country

fermenting: the process where microorganisms chemically break down food into new substances

leaching: the process of soaking and rinsing away unwanted (soluble) chemicals from a substance

lime: a white powder (calcium oxide) made through a chemical change that removes carbon dioxide from the calcium carbonate contained in plant matter or seashells

ochre: an earth-based pigment containing iron(III) oxide used for thousands of years by First Nations Peoples for painting, art and ceremony

thermoplastic: a substance that becomes plastic when heated and hardens when cooled, and can undergo these processes repeatedly

Key idea: Matter and energy

For tens of thousands of years, First Nations Peoples have harnessed physical and chemical changes to care for Country, prepare food and create medicines and tools. Through practices like cultural burning, fire has been used to promote plant growth and maintain ecosystems. Chemical reactions have also been applied to transform materials, such as heating ochre, resins, or plants and seashells to create pigments or lime. From detoxifying plants to preparing medicinal remedies, these processes demonstrate a sophisticated understanding of chemistry and its role in sustaining life and culture.

First Nations Peoples use fire to manage the land through chemical change

Fire has long been used by First Nations Peoples across Australia as a powerful tool to care for Country. **Cultural burning** involves setting controlled, low-intensity fires to promote plant growth, reduce fuel for wildfires and support ecosystems. When vegetation burns, it undergoes a chemical change, turning wood and plant matter into ash, gases and water vapour. These chemical reactions transform the materials involved and release heat energy. Unlike accidental bushfires, cultural burning is carefully planned, showing a deep knowledge of the seasons, weather and landscape, which was developed over many millennia. This method supports biodiversity and demonstrates sophisticated understanding of how chemical change can be harnessed to care for the land.



Figure 4.14: Combustion reactions have traditionally been used by First Nations Peoples in cultural burning to care for Country.

Heating and treating materials creates useful substances

First Nations Peoples have long known that applying heat to natural materials can change their properties and make them more useful. For example, heating **ochre** can change its colour through chemical reactions, allowing it to be used in art, decoration and cultural practices. Burning seashells or specific species of plants that are rich in the compound calcium carbonate (CaCO_3) causes a chemical change that produces a white powder called **lime**, or calcium oxide (CaO), by removing carbon dioxide (CO_2). Lime was used by First Nations Peoples as a binding material in paints and to make tools, as well as in the preparation of bush medicines. These processes show how heating and treating materials cause chemical transformations that result in valuable substances for cultural and practical use.



▲ **Figure 4.16:** Seashells and specific species of plants contain calcium carbonate which can be chemically broken down to form lime, a substance used for many purposes by First Nations Peoples.

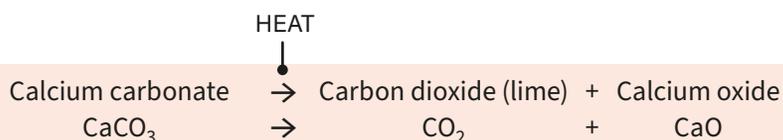


Figure 4.15: This word equation represents the chemical reaction First Nations Peoples create to produce lime from the calcium carbonate found in specific plants and seashells. The lime is then used in a variety of ways.

Figure 4.17: Raw seeds from a cycad cone are toxic and must be processed appropriately before they are safe to eat.

Traditional food preparation involves chemical changes to remove toxins

First Nations Peoples have also developed sophisticated methods to make toxic plants safe to eat through chemical changes during food preparation. For example, cycad seeds, which contain harmful toxins when raw, have been detoxified by crushing, soaking, leaching, fermenting and cooking. These processes help to break down or remove the toxins, making the seeds safe for consumption. Physical changes are used by rinsing away soluble toxins through soaking and **leaching** processes, while **fermenting** and cooking trigger chemical reactions that alter the toxins. These methods reflect a deep understanding of how chemical changes in food preparation can ensure safety and nourishment.



First Nations Peoples use thermoplastic resins to create tools

First Nations Peoples have always created a variety of tools to serve many different purposes. A key material in the creation of tools is **thermoplastic** resin. This adhesive substance is used to glue together the multiple parts that make up tools such as those used for hunting. One common resin comes from the tjanpi, also known as the spinifex plant, in the Central Desert region of Australia. The resin is extracted from the grass and then heated in the coals of a fire. When hot, it becomes malleable and sticky and can be shaped and used to stick other materials together. Once it has cooled, it forms a strong and hard bond.

Other types of resins are also useful for a variety of purposes, such as for waterproofing, in medicines, and in the creation of various moulds and decorative objects.

The use of resins has enabled a variety of useful tools to be created that have helped people to live well in their chosen locations.

Bush medicines are based on generations of chemical knowledge

For tens of thousands of years, First Nations Peoples have passed down knowledge of bush medicines – treatments made from plants and animals – based on careful observation, understanding of the properties of different substances in the environment and complex experimentation. Eucalyptus leaves, for example, contain chemical compounds that help to relieve respiratory problems and aid in healing wounds. Tea tree oil is rich in natural **antiseptic** compounds that fight infection. Table 4.1 summarises some of the most common bush medicines used by First Nations Peoples. These practices show how First Nations medicine, like Western medicine, is based on an understanding of chemistry and the ability to identify and use chemical changes in natural substances.

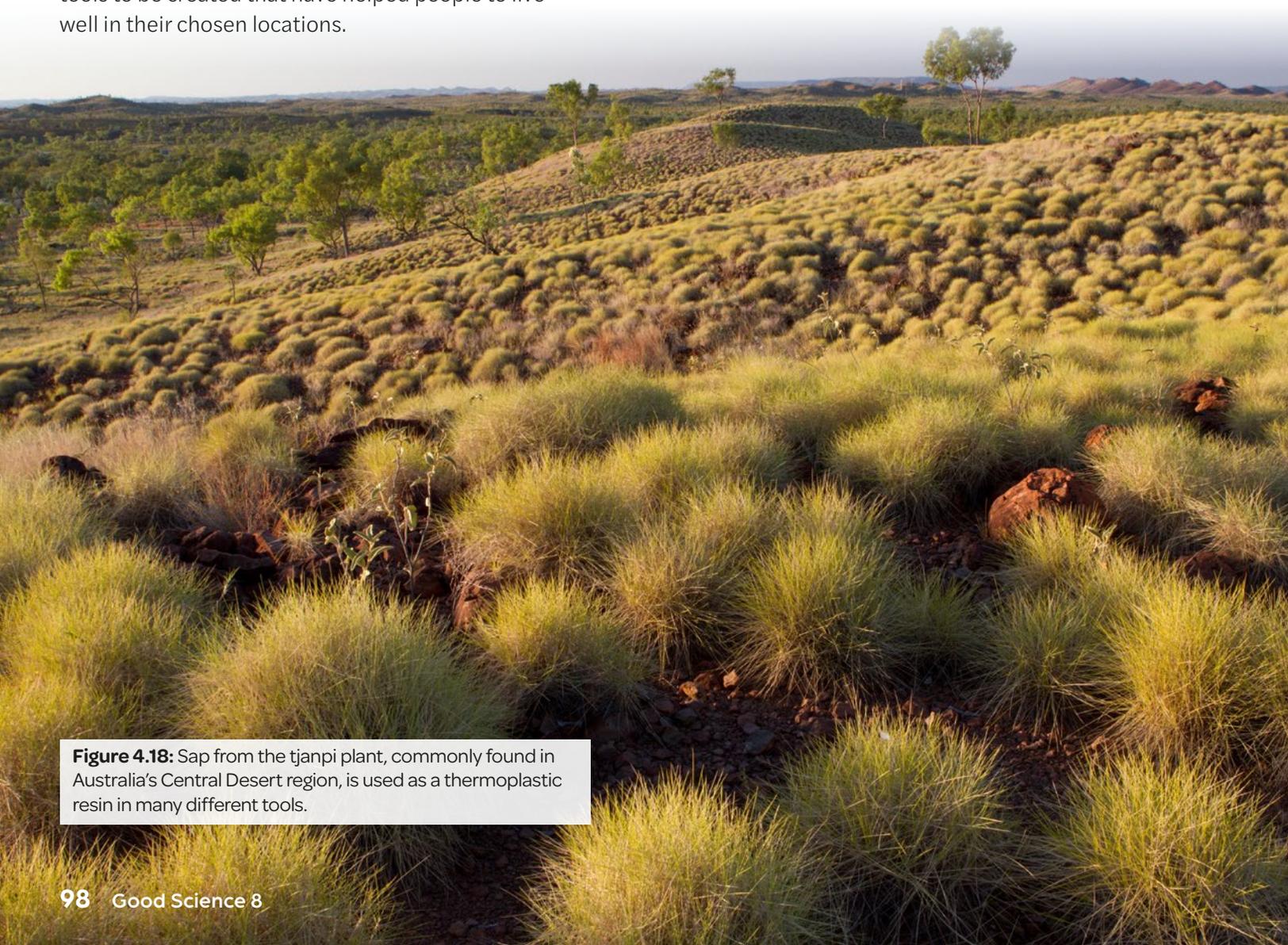


Figure 4.18: Sap from the tjanpi plant, commonly found in Australia's Central Desert region, is used as a thermoplastic resin in many different tools.

Table 4.1: Common bush medicines and their uses

Bush medicine	Uses
Eucalyptus	Leaves and oil used for coughs and colds and for healing wounds (antiseptic)
Tea tree	Oil used to treat skin infections; kills bacteria and fungi
Emu bush	Leaves used to sterilise sores and treat sore throats
Kakadu plum	Very high in vitamin C; boosts immunity and helps healing
Lemon myrtle	Leaves used in tea or poultices for calming and antibacterial effects
Sandalwood	Resin and oil used for skin irritation and inflammation
Billy goat plum	Used as a wash for cuts and infections
Witchetty grub	Crushed and applied to burns and skin rashes
Native mint	Leaves used in tea for colds, coughs and headaches
Chewing bush	Leaves used for pain relief and for treating eye problems



Figure 4.19: Oil extracted from leaves such as eucalyptus has chemical properties that can be used for medicinal purposes.

Learning Ladder

Chemical change

- 1 Identify the observation which indicates that ochre undergoes a chemical change when heated.
- 2 Describe how leaching creates a physical change rather than a chemical change.
- 3 Explain the chemical change that occurs when plant materials or seashells are burned to make lime.
- 4 Analyse and discuss the statement below.
Physically removing twigs and debris from bushlands might prevent harmful bushfires, but it will not provide the same benefits as controlled fires.
- 5 Evaluate the word equation in Figure 4.15 that represents the production of lime, in conjunction with the corresponding chemical formulas for each word. Discuss whether this representation upholds the law of conservation of mass.

Use and influence of science

- 1 Identify whether cultural burning addresses social, economic, ethical or environmental issues. Provide a reason for your choice.

- 2 Propose and describe how First Nations Peoples' traditional use of bush medicines has affected society.

Planning and conducting

p. 236

- 1 Conduct a search about how to make ochre.
- 2 List four items (substances and/or equipment) that may be required to make ochre.
- 3 Identify four hazards associated with the items listed for Question 2. Describe how risk could be minimised for each hazard.

Key idea: Matter and energy

Explain how the transformation of materials during cultural burning, ochre heating or the creation of lime demonstrates the flow of energy and the rearrangement of matter. Use at least one example in your response.

Success criteria

- I can describe how First Nations Peoples utilise physical and chemical changes in a variety of scientific ways.

4.5 ▶ Identifying gases produced in chemical reactions

Learning intention

At the end of this lesson, I will be able to explain how to test for and identify gases produced in chemical reactions, including oxygen, hydrogen, ammonia and carbon dioxide.

Key terms

acidic: having properties of an acid (e.g., corrosive); turns blue litmus paper red

basic: having properties of a base, opposite to an acid; turns red litmus paper blue

flammable: catches fire easily when exposed to a spark or flame

infer: to make an informed guess or conclusion based on evidence such as observations

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

litmus paper: special paper used to test whether a substance is acidic or basic by the colour; red = acidic, blue = basic

non-flammable: does not catch fire easily when exposed to a spark or flame

splint: wooden stick that can be lit to provide a flame or glowing tip

Investigation 4.5

Identifying gases produced in chemical reactions, p. 323

Key idea: Matter and energy

Some chemical reactions produce gaseous products. Many are colourless and odourless, so it can be practically impossible to identify them from their appearance alone. In this section, you will learn how to safely test for four common gases – oxygen, hydrogen, ammonia and carbon dioxide – by using simple tests to observe their properties.

Tests can be conducted to identify certain gases

The behaviour of gases reveals clues about their properties, which allows us to identify them through simple tests. Observations that are made can lead to **inferences**, which are informed predictions or conclusions drawn from gathered evidence. For example, if you see wet footprints on the floor, you could **infer** that someone walked through with wet feet or wet shoes, even if you did not see them do so. Simple tests can be conducted to collect evidence used to make inferences about the properties of a substance. The properties can then be used to identify gases that are generated during chemical reactions.

For example, if a gas is exposed to a flame and the flame goes out, you could infer that the gas is **non-flammable** – that is, it does not catch fire easily – based on the observation.

Figure 4.20: If warm water is added to aluminium and iodine, they will react to produce heat and bright purple iodine vapour.



Oxygen (O₂) can be identified using the glowing splint test

Oxygen gas is required for combustion reactions. Although oxygen itself is non-flammable, the more oxygen that is available, the easier it will be for materials to burn. The glowing splint test can be used to determine if a gas, such as oxygen, supports combustion.

During a reaction that may produce oxygen, a glowing wooden **splint** (not fully burning) can be exposed to the gas being produced. If the splint bursts back into flame, we can infer that the gas supports combustion, confirming that oxygen is present.



Hydrogen (H₂) can be identified using the lit splint test

Hydrogen gas is known to be **flammable**, meaning it will catch fire or explode when exposed to a flame. To test for hydrogen gas, collect the gas in a test tube and bring a lit wooden splint close to its opening. If hydrogen is present, it will react explosively with oxygen in the air and produce a small 'pop' sound. The sound and sometimes a tiny flash of flame are strong indicators of hydrogen's presence due to a mini explosion occurring in the test tube. This test demonstrates both a chemical change and a rapid release of energy.

Figure 4.22: If a lit splint is placed at the opening of a test tube containing hydrogen gas, the gas will react with a 'pop' sound and the splint will go out.



Ammonia (NH₃) can be identified using a combination of tests

Ammonia gas can be identified by its distinct properties. It is non-flammable, so it will extinguish a flame when exposed to a lit splint, unlike oxygen or hydrogen. However, carbon dioxide is also non-flammable, so more than just the splint test is required to confirm the presence of ammonia.

Ammonia is a **basic** gas, which means it will turn damp red **litmus paper** blue; a key indicator of a base (the opposite of an **acid**). It also has a strong, sharp smell, often recognised during the reaction of ammonium chloride with sodium hydroxide. These observations – lit splint test, red litmus test and odour – help to confirm whether ammonia has been produced in a chemical reaction.

Carbon dioxide (CO₂) can be identified using the lime water test

Carbon dioxide reacts readily in the presence of calcium to produce an insoluble white substance called calcium carbonate (CaCO₃). Lime water is the common name given to a solution of calcium hydroxide (CaOH) dissolved in water. Since we know that carbon dioxide reacts with calcium, gas generated in a chemical reaction can be bubbled through lime water to see if calcium carbonate (CaCO₃) will form. If the gas is carbon dioxide, the lime water will turn from clear to cloudy white or milky, as shown in Figure 4.25.

Carbon dioxide also puts out a flame, showing it does not support combustion. But this test cannot be used on its own, and there are many other gases that are non-flammable, such as ammonia. Observing both the lime water test and the lit splint test gives clear evidence of carbon dioxide gas being produced.



Figure 4.24: Carbon dioxide gas produced during a reaction can be seen as bubbles.



Figure 4.23: Red litmus paper turns blue when exposed to ammonia because ammonia is a basic gas.



Figure 4.25: As carbon dioxide is bubbled through lime water, insoluble calcium carbonate forms which is observed as a cloudy white precipitate.

Table 4.2: Different tests can be used to confirm the presence of different gases. Observations lead to inferences. A gas can be identified when your inferences match the properties of the suspected gas.

Suspected gas	Test	Observation	Inference
Oxygen	Glowing splint	Makes a flame burn brighter	Supports combustion but not flammable
Hydrogen	Lit splint	Explodes (with a pop) when exposed to a spark or flame	Flammable
Ammonia	<ul style="list-style-type: none"> ▪ Lit splint ▪ Red litmus 	<ul style="list-style-type: none"> ▪ Smothers/puts out a flame ▪ Turns red litmus paper blue 	<ul style="list-style-type: none"> ▪ Non-flammable ▪ Basic (not acidic)
Carbon dioxide	<ul style="list-style-type: none"> ▪ Lit splint ▪ Bubble through lime water 	<ul style="list-style-type: none"> ▪ Smothers/puts out a flame ▪ Turns lime water cloudy-white 	<ul style="list-style-type: none"> ▪ Non-flammable ▪ Contains carbon which reacts with calcium in lime water to form a white calcium carbonate precipitate

Learning Ladder

Chemical change

- 1 Identify what is observed when carbon dioxide is bubbled through clear lime water.
- 2 Propose how you would describe to a friend that water turning cloudy indicates a chemical change, rather than a physical change.
- 3 Complete the sentences below.
 - a When _____ gas is exposed to a flame, it will undergo combustion because it is highly _____. It reacts with _____ to form water (H₂O).
 - b Explain how the sentences from part a indicate that a chemical reaction has occurred. In your response, refer to the rearrangement of atoms.
- 4 Explain how to differentiate between ammonia and carbon dioxide gas evolved from a reaction, given that both would smother a flame.
- 5 Evaluate the following chemical equation used to represent the change that calcium hydroxide (Ca(OH)₂; lime water) undergoes when exposed to carbon dioxide:

$$\text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O}$$
 In your evaluation:
 - a State whether the equation follows the law of conservation of mass. Explain why or why not.
 - b Suggest what property calcium carbonate (CaCO₃) must have in order to be identified. Suggest how this information could be included in the equation.

Use and influence of science

- 1 Complete the sentence below.
Being able to identify the type of _____ that evolves from a _____ reaction can be helpful in keeping _____ safe from harmful fumes.

- 2 Describe how scientific knowledge that led to the invention of carbon monoxide detectors has affected society, given that carbon monoxide is toxic.

Evaluating

p. 249

Refer to Investigation 4.5 on page 323.

- 1 Identify which of the following is an assumption made in the investigation:
 - A Hydrogen is the only gas that is flammable.
 - B Oxygen gas will smother a flame.
 - C The lime water is contaminated.
- 2 True or false?
When testing for hydrogen gas, using a test tube that is too big is a systematic error (no 'pop' sound), leading to a false negative result.
Provide a reason for your response.
- 3 Explain the scientific theory that supports the expectation that hydrogen gas makes a 'pop' sound when ignited inside a test tube.

Key idea: Matter and energy

Zinc metal is combined in a test tube with hydrochloric acid. Students notice bubbles forming and the test tube becomes warm. The lit splint test is carried out, resulting in a sharp 'pop' sound. Explain how these observations indicate that a chemical change has occurred. In your response, refer to the rearrangement of matter and transfer of energy. Use diagrams and/or word equations to support your response.

Success criteria

- I can select an appropriate test to conduct to confirm whether oxygen, hydrogen, ammonia or carbon dioxide evolves from a reaction.
- I can make links between observations made of gases produced in chemical reactions and their properties.

4.6 ▶ Key idea: Matter and energy – energy changes in chemical reactions

Learning intention

At the end of this lesson, I will be able to:

- identify that chemical reactions involve a transfer of energy
- distinguish between exothermic and endothermic chemical reactions.

Key terms

endothermic: a reaction that absorbs energy in the form of heat

exothermic: a reaction that releases energy in the form of heat

Investigation 4.6

Exothermic and endothermic reactions, p. 325

Key idea: Matter and energy

Chemical reactions involve more than just elements and compounds; they also involve energy, usually heat. Some reactions release heat. Others require heat to be added. Without energy being transferred, chemical reactions would not happen.

Exothermic reactions release heat, and endothermic reactions absorb heat

In **exothermic** reactions, the reactants have more energy than the products. This additional energy is released as heat. Respiration and combustion are both examples of exothermic reactions.

In **endothermic** reactions, the products have more energy than the reactants. For these reactions to happen, they require energy from their surroundings, usually in the form of heat. Endothermic reactions include photosynthesis, bread-baking, and decomposition of water (H_2O) into oxygen and hydrogen gas.

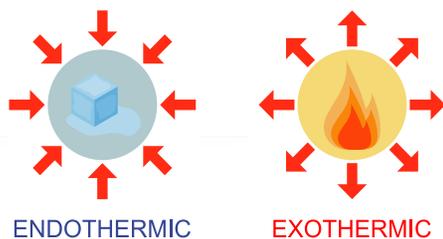


Figure 4.26: Endothermic reactions absorb energy, whereas exothermic reactions release energy.

Figure 4.27: Fuel being burnt in a rocket launch is an example of an exothermic reaction.



Bonds break and form during chemical reactions

During a chemical reaction, bonds in the reactants break and new bonds form to make products. Energy is needed to break the bonds of the reactants and is released when new bonds form in the products.

When water decomposes, bonds within water molecules break. New bonds form between oxygen atoms to produce oxygen gas and between hydrogen atoms to produce hydrogen gas (see Figure 4.29). Depending on the atoms involved, different amounts of energy are required to break and form bonds.

Figure 4.28: Total energy levels of reactants and products in an (a) exothermic reaction and (b) endothermic reaction

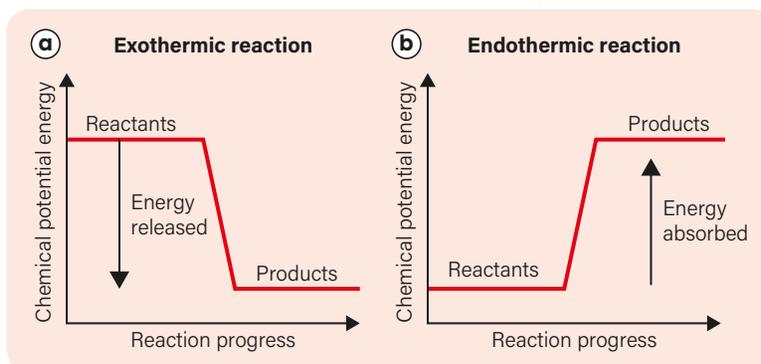
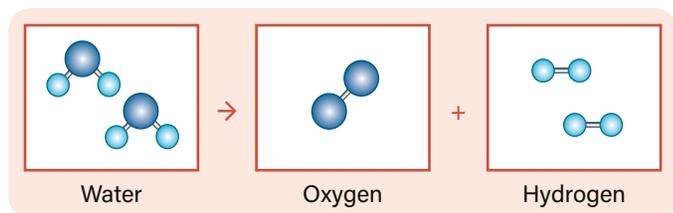


Figure 4.29: Water decomposing into oxygen and hydrogen gas is an endothermic reaction.



Chemical reactions release or absorb heat

All reactions require energy to get started, but that does not mean all reactions are endothermic.

An exothermic reaction occurs when the energy needed to break the bonds in the reactants is less than that released when new bonds are made in the products. This additional energy is released as heat

and the temperature of the surroundings increases. Overall, these reactions release energy.

Chemical equations for exothermic reactions can be represented like this:



In an endothermic reaction, the energy required to break the bonds in the reactants is greater than the energy released when the products are formed. This means that, overall, the reaction absorbs energy from its surroundings, so the temperature decreases around the reaction container or surroundings.

Chemical equations for endothermic reactions can be represented like this:



Learning Ladder

Chemical change

- 1 Identify whether the temperature inside the reaction container will increase or decrease for the following types of reactions.
 - a Exothermic
 - b Endothermic
- 2 Classify the following observations of temperature change as a physical or chemical change:
 - a Hot coffee gets cold after a while.
 - b Two cold solutions are mixed together and the temperature suddenly increases.
- 3 Identify the following changes as exothermic or endothermic. Give a reason for each choice.
 - a Ice melting
 - b Burning wood in a campfire
 - c Using an instant cold pack on an injury

Use and influence of science

- 1 Propose why exothermic reactions that release large amounts of energy very quickly might be a socio-scientific issue.
- 2 Identify and describe how two common endothermic and exothermic reactions are useful in society.
- 3 Propose and explain potential ethical and environmental impacts of scientific advances related to nuclear energy, considering that nuclear reactions release millions of times more energy than chemical reactions.

Evaluating

p. 249

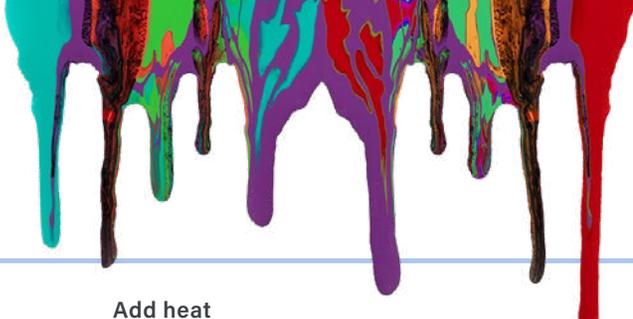
Refer to Investigation 4.6 on page 325. Read the aim, materials and method.

- 1 Identify two sources of error that could affect the accuracy of the temperature change measurements.
- 2 Describe the types of errors identified in Question 1, including how they might impact the results.
- 3 Explain the theory that will be used to determine whether each part of the investigation (A–E) is exothermic or endothermic.
- 4 Suppose the initial temperature of part E was 25 °C and the final temperature was 45 °C. Two hours later, the temperature was 20 °C.
 - a Predict whether the reaction is exothermic or endothermic.
 - b Construct an evidence-based statement to justify your prediction that considers all the data values.

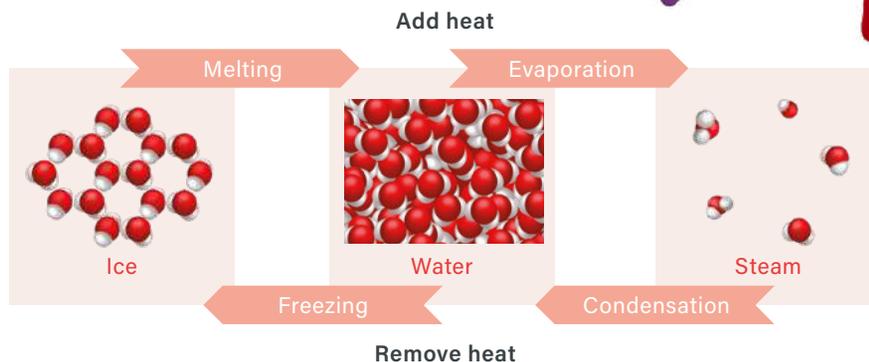
Success criteria

- I can describe exothermic and endothermic reactions.
- I can explain why chemical reactions involve energy transfer.

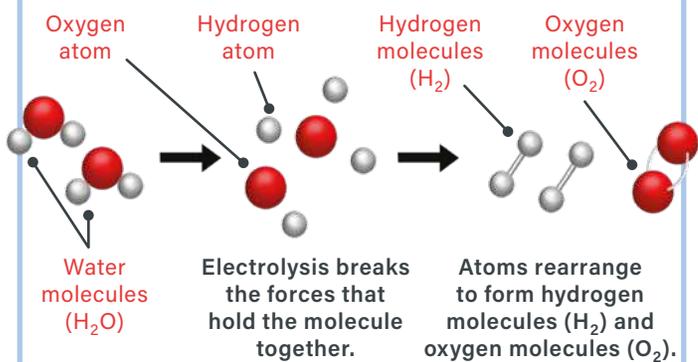
► Summary



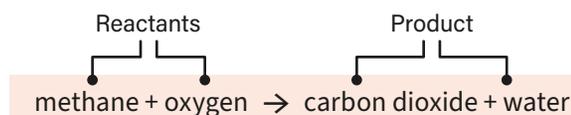
- A physical change is a change in appearance, not in properties; no new substance is formed, and the process is reversible. For example, paint undergoes a physical change when it dries.
- Particles do not change during a physical change.



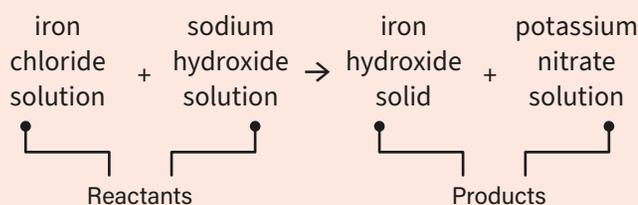
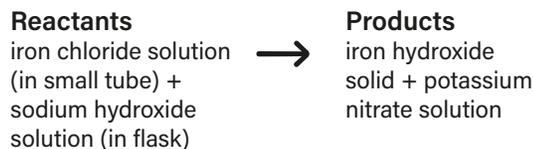
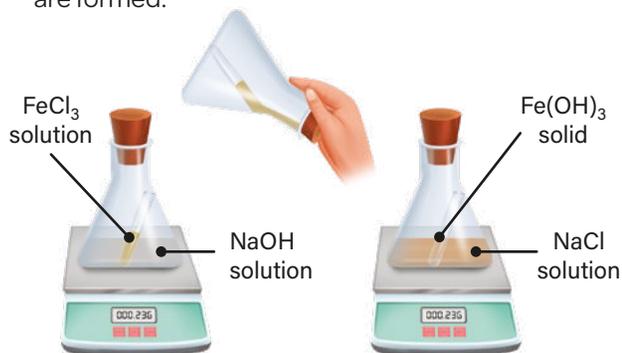
- When a chemical change occurs, new substances are formed.
- Evidence of a chemical change can be seen when:
 - there is a change in colour
 - gas is produced (bubbles)
 - a new substance forms/appears
 - there is a temperature change (it heats up or cools down)
 - light is observed
 - a precipitate (solid particles in solution) forms.
- Particles change during a chemical change.



- Chemical change can be represented by word equations.



- The law of conservation of mass is maintained, even though new substances (such as a precipitate) are formed.



- First Nations Peoples use physical and chemical changes in a variety of ways.
 - Fire is used for cultural burning to manage the land.
 - Materials are heated and treated to alter their properties.
 - Food is prepared by physically and chemically removing toxins.
 - Bush medicines are developed.

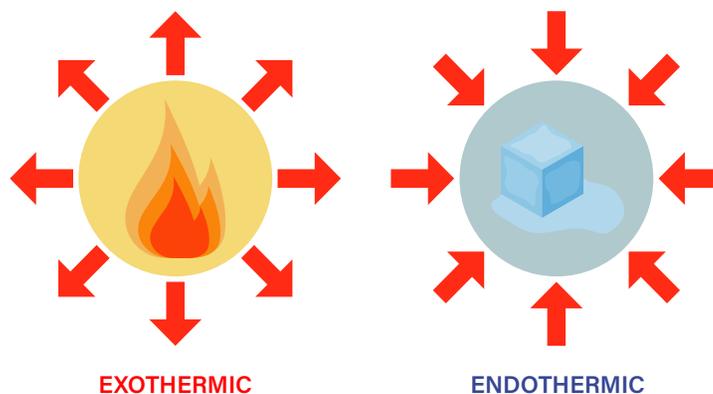


- Gases produced in chemical reaction can be identified using simple tests.

Suspected gas	Test	Observation	Inference
Oxygen	Glowing splint	Makes a flame burn brighter	Supports combustion but not flammable
Hydrogen	Lit splint	Explodes (with a pop) when exposed to a spark or flame	Flammable
Ammonia	<ul style="list-style-type: none"> • Lit splint • Red litmus 	<ul style="list-style-type: none"> • Smothers/puts out a flame • Turns red litmus paper blue 	<ul style="list-style-type: none"> • Non-flammable • Basic (not acidic)
Carbon dioxide	<ul style="list-style-type: none"> • Lit splint • Bubble through lime water 	<ul style="list-style-type: none"> • Smothers/puts out a flame • Turns lime water cloudy-white 	<ul style="list-style-type: none"> • Non-flammable • Contains carbon which reacts with calcium in lime water to form a white calcium carbonate precipitate

Key idea: Matter and energy

- Exothermic chemical reactions release energy, which causes the surrounding area to increase in temperature.
- Endothermic chemical reactions absorb energy, which causes the surrounding area to decrease in temperature.



Masterclass

Steps in progression

1

2

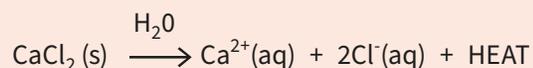
Science understanding	Chemical change	Identify at least two things you might observe when an exothermic reaction takes place.	Classify the reaction used in cold packs as a physical change or a chemical change. Provide a reason for your response.
Science as a human endeavour	Nature and development of science	Complete the sentence below. _____ thermic reactions could present problems because they can release large amounts of _____ in the form of explosions.	Describe a situation where it might be important for a physiotherapist to work with a chemist to produce therapy packs for rehabilitation.
	Use and influence of science	Toxic chemicals can be used in hot and cold packs. Identify whether this may present environmental, ethical or social issues. Provide a reason for your response.	Describe how the invention of hot and cold packs has affected society in a positive way. Provide examples.
Science inquiry	Planning and conducting	You are asked to investigate the effectiveness of heat packs that use different reactants. Identify three pieces of equipment you might need in order to carry out the investigation.	Identify three hazards presented by the equipment identified in step 1 and describe how you would reduce the associated risks.
	Evaluating	Identify the following statement as an assumption or error in the collection of data: <i>The temperature increase of a reaction indicates how much energy is released.</i>	Identify the following error as random or systematic: <i>When measuring the temperature decrease of an endothermic reaction, the sun was sometimes shining in the window as clouds passed.</i>

Using energy from reactions

Hot and cold packs are great examples of how physical and chemical reactions can release or absorb energy, creating heat or cold. These packs use specific reactions either to warm up or to cool down, based on the type of chemicals they contain.

In a hot pack, a common reaction involves calcium chloride (CaCl_2). When calcium chloride salt is physically dissolved in water, it releases energy in an exothermic reaction observed as heat, which increases the temperature of the area surrounding the chemical reaction. No new substances are formed

in this example, but since bonds are broken between calcium and chlorine, and new bonds are formed with water molecules in solution, there is a transfer of energy. In this exothermic process, energy is released into the surroundings, causing the temperature of the pack to rise, making it feel warm. This reaction is often used in reusable hand warmers and in some therapeutic packs for sore muscles.



Demonstrate your understanding

3

Explain why dissolving solid CaCl_2 in water to produce heat is a physical change. In your response, refer to the rearrangement of atoms.

4

- a** Analyse the following statement to determine if it is true or false:
Only chemical changes release and absorb energy.
- b** Justify your response with scientific theory and give an example.

5

- a** Construct a word equation to represent the reaction that takes place in a typical instant cold pack.
- b** Evaluate how using word equations can be useful in understanding physical and chemical changes.

Propose and explain scientific evidence that may have led to the use today of less-toxic chemicals in cold packs.

Analyse the structure of word equations used to represent endothermic and exothermic reactions. Discuss why it is helpful to include 'HEAT' in the reactants or products.

Research different substances that are used to make different brands of hot and cold packs. Analyse the different worldviews that may have contributed to their production, based on where they are produced in the world.

Explain the environmental impacts of using disposable, single-use cold packs as compared to using reusable ice packs kept in the freezer.

- Discuss how using biodegradable plastics in single-use cold packs could:
- a** address environmental issues.
- b** create new socio-scientific issues.

Evaluate the following suggestion:
Hot and cold packs should be advertised at all sporting events so that more people buy them and thus increase company profits.

- a** Identify the independent variable for investigating presented in step 1.
- b** Propose what the dependent variable could be, including units.
- c** Explain how you would maintain a fair test.

Propose and discuss the tools you would require in order to generate and record data with precision.

Design a step-by-step method to conduct this investigation. Include procedural details to ensure the investigation is safe, ethical and reproducible.

Science
how-to
p. 236

Experimental data collected alongside the observations given in step 2 show that between 10 and 20 seconds, the temperature did not decrease, but between 20 and 30 seconds it dropped 10 degrees. Use scientific theory and reference to errors to explain these results.

Construct an evidence-based statement to conclude that the reaction from steps 2 and 3 is endothermic, even though the temperature did not decrease between 10 and 20 seconds.

Evaluate your statement from step 4. Discuss whether conducting the investigation again would be useful in addressing conflicting evidence and unanswered questions.

Science
how-to
p. 249

Cold packs work in a similar way but require different reactants that undergo endothermic reactions. They often contain ammonium nitrate (NH_4NO_3) or urea inside a water-filled pouch. When you squeeze the pack to break the inner pouch, the urea physically dissolves in water and absorbs heat in an endothermic reaction. In an endothermic reaction, energy is absorbed from the surroundings, causing the temperature of the pack to drop, making it feel cold.

These reactions are useful in everyday products for providing quick heat or coldness and help to illustrate how chemical reactions can change energy to produce practical effects.



Figure 4.31: Endothermic reactions are used in instant ice packs. They are often included in first-aid kits to enable the immediate application of a cold compress to an injured part of the body.

Figure 4.30: Exothermic reactions can be contained in a package to be marketed as instant heat packs for warming hands and feet.



5.0 Plate tectonics

The theory of plate tectonics explains how Earth functions from a geological point of view. This one theory accounts for why mountain ranges have formed where they are, why volcanoes erupt, why we observe certain patterns in the fossil record, and why animals and plants on one continent can be related to those on the other side of the planet.

Figure 5.1: Undersea mountain ranges can form along tectonic plate boundaries. Most of these are connected, forming the longest mountain range on Earth.

Learning Ladder

The Learning Ladder for each chapter maps the Science Understanding, Science as a Human Endeavour and Science Inquiry strands that will be covered. Each ladder has five levels of progression, called steps. To climb the ladders, you need to develop fluency at each step. This will help you develop the ability to complete tasks that are more complex.

5	I can evaluate evidence that supports the theory of plate tectonics	I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations
4	I can discuss geological phenomena, including volcanoes and earthquakes, in terms of tectonic activity	I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues
3	I can explain how geological features are formed by tectonic activity	I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances
2	I can distinguish between different types of tectonic activity	I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society
1	I can identify geological features	I can recognise scientific problems and solutions	I can identify socio-scientific issues
Steps in progression	Earth and space science: Plate tectonics	Nature and development of science	Use and influence of science
	Science understanding	Science as a human endeavour	



Figure 5.2: Topographic map showing tectonic plate boundaries under the ocean.

I can design and conduct reproducible investigations that consider safety, ethical and procedural factors	I can evaluate conclusions and claims with reference to conflicting evidence and unanswered questions	5
I can generate and record data with precision, using digital tools as appropriate	I can create evidence-based arguments to justify conclusions or evaluate claims	4
I can distinguish between variables to be changed, measured and controlled in an investigation	I can use science-based explanations to support investigation findings	3
I can describe ways to minimise risks for a range of investigations	I can describe different types of errors in an investigation method	2
I can identify and select appropriate equipment for scientific investigations	I can identify errors and assumptions in an investigation	1
Planning and conducting	Evaluating	Steps in progression
Science inquiry		

5.1 ▶ Earth's structure

Learning intention

At the end of this lesson, I will be able to describe Earth's structure in terms of the core, mantle, crust and lithosphere.

Key terms

asthenosphere: the portion of Earth's mantle underneath the lithosphere that can flow

atmosphere: the layer of gas that surrounds Earth

core: Earth's central layer, made up of a liquid outer core and a solid inner core

crust: Earth's thin outer layer, made up of continental crust and oceanic crust

density: how heavy something is for its size; mass divided by volume

lithosphere: Earth's rigid outer zone (crust and most of the upper mantle), made up of tectonic plates

mantle: Earth's middle layer, made up of an upper mantle and a lower mantle

tectonic plate: a section of Earth's lithosphere

Investigation 5.1

Modelling Earth's structure, p. 328

Key idea: Stability and change

When Earth formed approximately 4.5 billion years ago, it was a ball of molten (melted) rock. As it gradually cooled, this molten rock separated into three main layers. The most dense metallic elements moved to the centre to form the core. Elements of medium density formed the mantle, and the least dense elements moved to the surface to form its crust and atmosphere.

Discovering more about Earth

The deepest hole that has been drilled into the crust is just over 12 kilometres, so how do we know about the other layers of the Earth? Most of our understanding of those layers has come from analysing the patterns of seismic waves produced by earthquakes. Geologists also get information from looking at magma and rocks that have formed deep down within Earth.

Earth's core is solid on the inside, liquid on the outside

Earth's centre, where elements are of the greatest **density**, is the **core**. It is made up of a very hot liquid outer core (2200 km thick) and a solid inner core (1250 km thick). The core is mostly iron (85%), with a small amount of nickel (5%) and some lighter elements, including oxygen and silicon. The pressure in the inner core is so immense that the atoms are forced together to form a solid.

The mantle sits between Earth's core and the crust

Earth's thickest layer is the **mantle** (2900 km thick).

Even though the mantle is made of solid rock, the very high temperatures and pressures enable the rock to flow very slowly. The process is similar to what you might see when you put a blob of silly putty on the edge of a desk.

The rocks in the mantle are mostly made up of oxygen (48.9%), silicon (21.5%) and magnesium (22.8%). Other elements include iron, aluminium, calcium, sodium and potassium. The processes in the mantle cause a lot of the change and movement on Earth's surface. The mantle can be thought of as two parts: the upper mantle and the lower mantle.

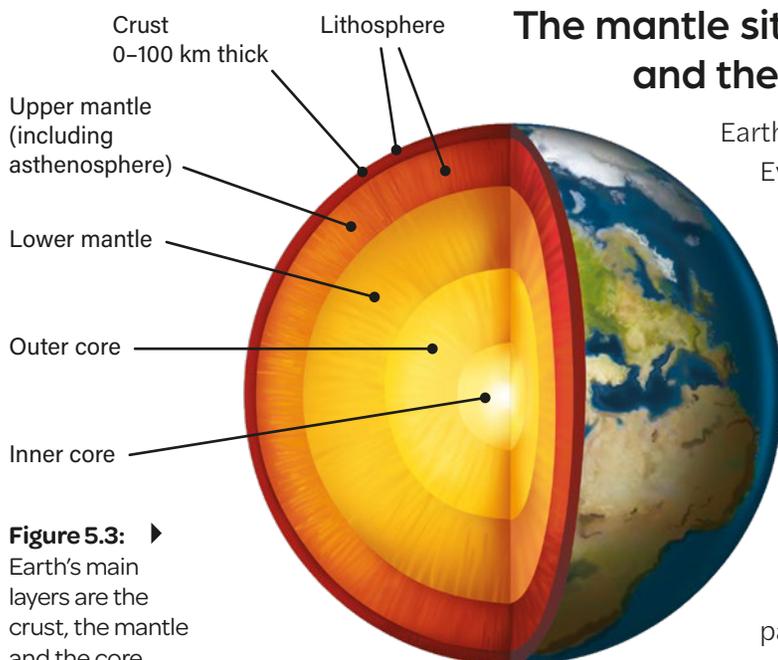


Figure 5.3: ▶ Earth's main layers are the crust, the mantle and the core.

The crust is Earth's thin outer layer

The **crust** is Earth's hard outer shell and its thinnest layer. The crust consists of a variety of rocks that are mostly made of the elements oxygen (46.1%), silicon (28.2%) and aluminium (8.2%). Other elements include iron, calcium and sodium. There are two types of crust: continental crust and oceanic crust. The continental crust forms the continents and the shallow seas around the continents. It covers about 40 per cent of Earth's surface and is 10–100 kilometres thick. The oceanic crust is formed in Earth's ocean basins. It covers about 60 per cent of Earth's surface and is 5–7 kilometres thick.

Tectonic plates move around on the asthenosphere

The **lithosphere** is Earth's rigid, rocky outer zone. It includes the crust and most of the upper mantle. The lithosphere is made up of **tectonic plates** that 'float' and move around on a zone called the **asthenosphere**. There are 15 major tectonic plates and some smaller ones.

The asthenosphere is a thin zone of the upper mantle that sits just beneath the lithosphere. The rocks here are at very high temperatures and pressures, so they almost melt. This makes them very viscous and ductile compared to other parts of the mantle. As a result, the tectonic plates of the lithosphere move and act on each other, which can cause earthquakes and volcanoes at Earth's surface.

Figure 5.4:
Earth's atmosphere is mostly made up of nitrogen and oxygen gas.

The atmosphere is a layer of gas

The **atmosphere** is the 600-kilometre-thick layer of gas that surrounds Earth. It protects life on Earth from harmful radiation by either absorbing the radiation or reflecting it back into space. The atmosphere is made up of nitrogen (78%) and oxygen (21%), along with tiny quantities of argon, carbon, neon and helium.

Learning Ladder

Plate tectonics

- 1 Identify Earth's thickest and thinnest layers.
- 2 Describe the difference between the core and the mantle.
- 3 Explain how heat energy in the asthenosphere helps the tectonic plates to move.
- 4 Discuss how the lithosphere interacts with the asthenosphere.
- 5 Evaluate whether the type of evidence collected to learn about the structure inside Earth is suitable.

Nature and development of science

- 1 Identify the data geologists have used to tell them more about the structure of the mantle and the core.
- 2 Propose what disciplines of science might work together to find out more about the structure of Earth.

Planning and conducting

p. 236

Read through investigation 5.1 on page 328 before answering the questions below.

- 1 Draw scientific diagrams of the scientific equipment used in the investigation.
- 2 **a** Identify at least two hazards associated with the investigation.
b Describe techniques you would use to minimise the risks associated with each hazard.
- 3 For this investigation, identify the:
a independent variable.
b dependent variable.
c controlled variables.

Key idea: Stability and change

Describe how the structure of Earth has changed from when it was a ball of molten rock.

Success criteria

- I can name the main layers of Earth.
- I can describe the composition of each layer.

5.2 Evidence for plate tectonics



Figure 5.5: These divers are floating in a water-filled rift valley between the North American Plate and the Eurasian Plate in Iceland.

For a long time, people thought that the continents were in the same place as when Earth first formed. However, evidence gathered in the first half of the 20th century indicated that the continents are moving. The theory of plate tectonics uses many different pieces of evidence to explain the movement of the continents and the formation of different landforms on the Earth's crust due to the interaction and movement of tectonic plates.

Learning intention

At the end of this lesson, I will be able to outline the evidence for the theory of plate tectonics.

Key terms

cartographer: a person who makes maps

continental drift: the theory that the continents have moved position over time

mid-ocean ridge: a long chain of mountains under the ocean formed by plate tectonics

rift valley: a valley formed when a continent is being pulled apart

subduction: when one tectonic plate moves underneath another

Investigation 5.2

Modelling seafloor spreading, p. 329

Key idea: Stability and change

The continents move over time

In 1912, German meteorologist Alfred Wegener published his theory on **continental drift**. He proposed that the continents had once been joined in one large landmass that he called Pangaea. Over time, this landmass split apart and the continents moved to their current positions.

Wegener found evidence for past glacial climates in equatorial Africa and tropical climates in north-western Europe. The only way to explain this was that the continents had moved.



Figure 5.6: Wegener proposed that the continents had once been joined in one large landmass called Pangaea. Over time, the continents split into two supercontinents (Gondwana and Laurasia) and then into the continents of today.

Further evidence to support Wegener's theory includes:

- how the continental shelves of continents fit together like pieces of a jigsaw
- identical rock formations on either side of the Atlantic Ocean
- identical plant and animal fossils on different continents separated by oceans.

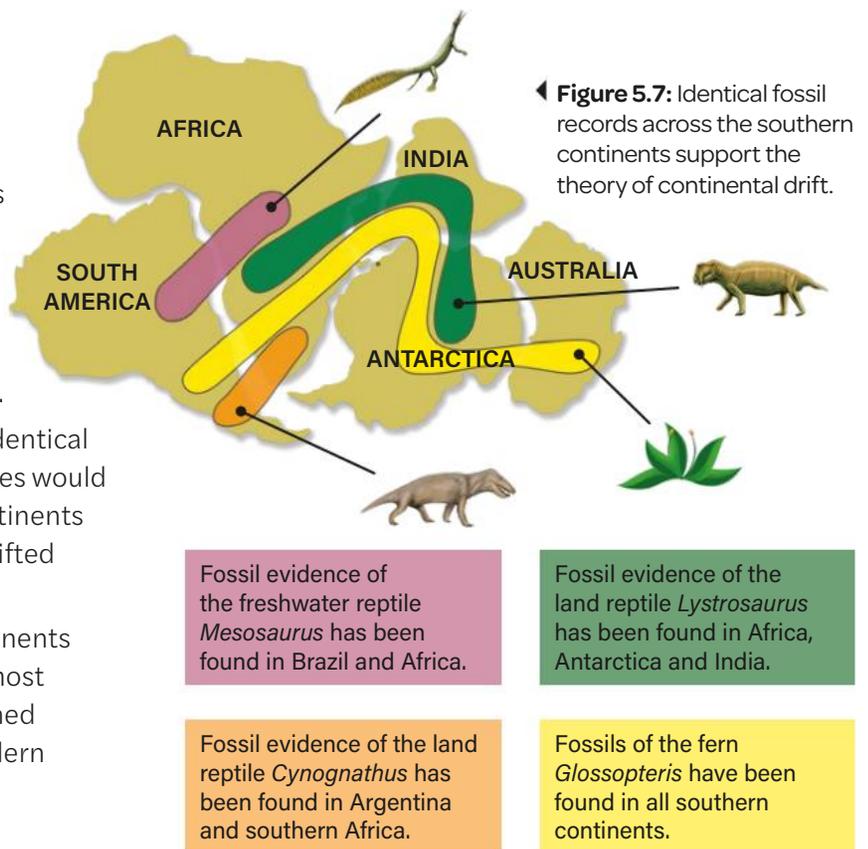
Wegener reasoned that it was unlikely that identical rocks would have formed and identical species would have evolved so far apart. Therefore, the continents must have once been joined together and drifted apart over time to their current positions.

Wegener could not suggest how the continents moved, so his theory was not supported by most scientists. He continually refined and published his ideas as new evidence came to light. Modern geologists accept his theory as correct.

The sea floor is spreading apart

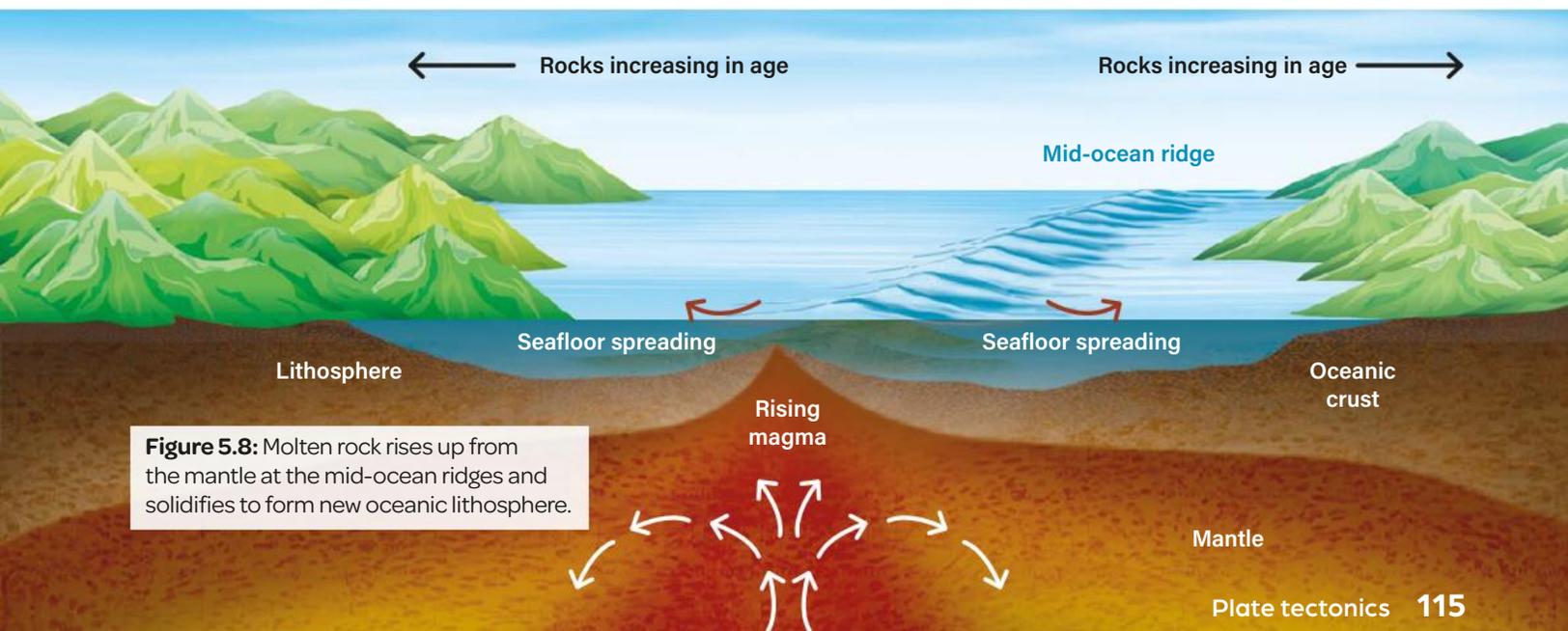
Seafloor spreading happens when molten rock rises up from the mantle at the **mid-ocean ridges** and solidifies to form new oceanic lithosphere. There are four main pieces of evidence to show that the sea floor is spreading.

- *Rift valleys along mid-ocean ridges:* In 1952, US geologist Marie Tharp found that there was a V-shaped valley running along the bottom of the Atlantic Ocean. This **rift valley** is where the new lithosphere is formed.
- *Magnetic striping:* As lava cools, the magnetic minerals in it align with Earth's magnetic poles,



just like a compass needle does. The positions of the magnetic poles have changed over time, even reversed. As a result, in rocks formed at different times, the minerals are aligned differently.

- *Depth of sediments:* The depth of sediments on the oceanic crust are deeper closer to the continents. This implies that those rocks are older because there has been more time for the sediment to accumulate.
- *Age of the sea floor:* Radiometric dating shows that the oceanic crust closer to the continents is much older than the rock closer to the mid-ocean ridges.



Old lithosphere is subducted

If new lithosphere is being formed at mid-ocean ridges, why is Earth not getting larger? Scientists discovered that this is because of **subduction** – here the edge of one tectonic plate is pushed under the one next to it.

Geologists use three main pieces of evidence to show that the lithosphere is being subducted.

- *Ocean trenches:* Seafloor mapping shows the existence of deep ocean trenches. We now know this is where two tectonic plates are colliding.
- *Earthquake locations:* Earthquakes get deeper further away from ocean trenches. This is evidence that one plate is moving down under the other. Regions where this happens are called Wadati–Benioff zones, after the scientists who discovered them.
- *Volcano chains above such zones:* The formation of chains of volcanoes above a Wadati–Benioff zone shows that one plate is moving under another. When a plate subducts, the subducting lithosphere starts to melt and the molten rock rises to the surface to form volcanoes.

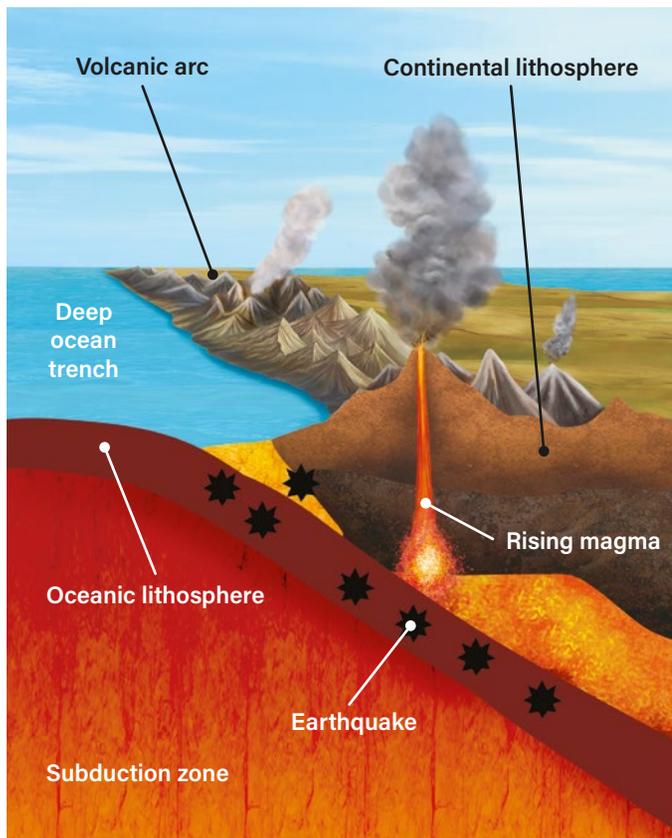


Figure 5.9: Denser crust subducts underneath less-dense crust. This forms a deep ocean trench, causes deep earthquakes and forms a chain of volcanoes.

Marie Tharp – the scientist who mapped the sea floor

Marie Tharp (1920–2006) was an American geologist and **cartographer**. In the 1950s, she used sonar readings to help her construct a topographical map of the floor of the Atlantic Ocean. At that time, little was known about the ocean floor and it was thought to be mostly flat. Tharp was not allowed on the ships themselves, because having a woman on board was once thought to bring bad luck. Instead, she interpreted the data after the ships returned to port.

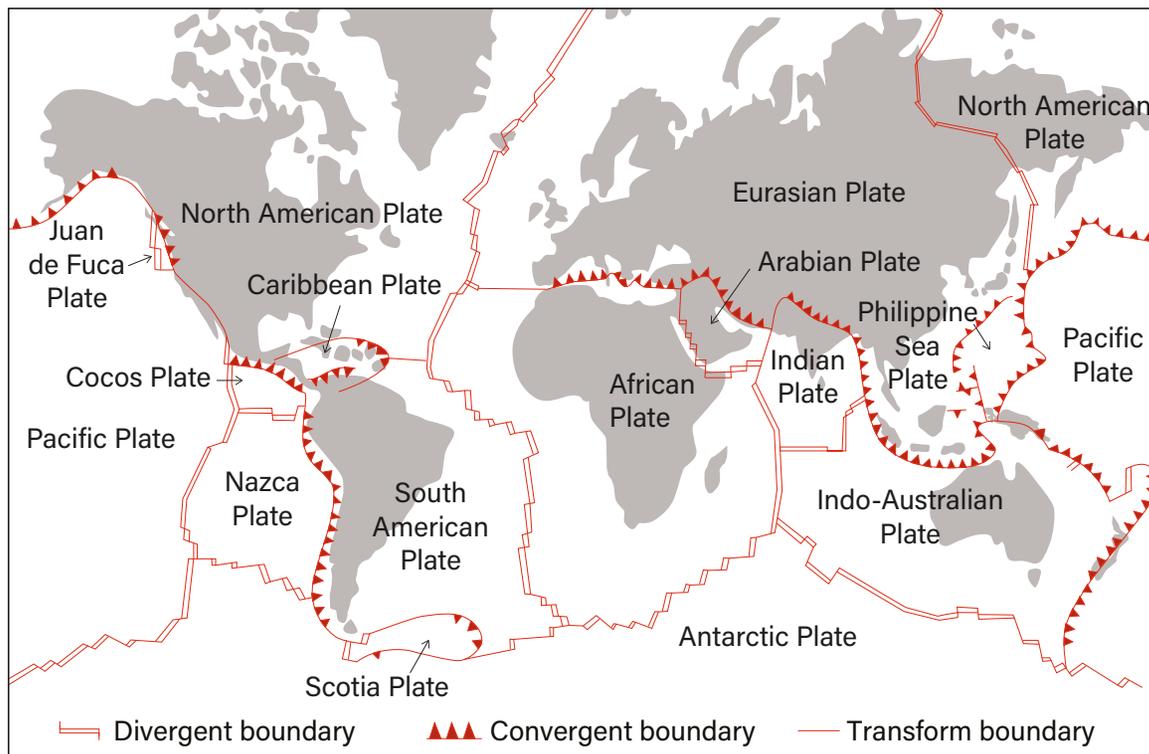
Tharp's map clearly showed a ridge of mountains running down the Atlantic Ocean with a deep valley in between them. She suggested that it was the same as the rift valleys observed on land. This was initially dismissed by her male colleagues as 'girl talk'. It was only when her data was reanalysed and was found to show the same pattern that her findings began to be taken seriously.

At the same time as Tharp was working on her map, a colleague was plotting earthquake epicentres in the Atlantic Ocean, and they soon realised that their maps overlapped. This provided evidence that movement was happening at the Mid-Atlantic Ridge, indicating that this is where the continents are splitting apart. Marie Tharp's work was a key piece of evidence for the theory of plate tectonics.



Figure 5.10: Marie Tharp's map of the floor of the Atlantic Ocean led her to discover the Mid-Atlantic Ridge – a piece of crucial evidence supporting the theory of plate tectonics.

Figure 5.11: ▶ Tectonic plate boundaries and movement. Most earthquake epicentres are located on plate boundaries and are caused by the movement of the plates.



Learning Ladder

Plate tectonics

- 1 Copy and complete the sentence below.
The theory of _____ states that Earth's continents were once _____ together and moved _____ over time.
- 2 Describe the evidence Wegener used to explain why continents must have moved over time.
- 3 Explain one piece of evidence for the theory of plate tectonics that is observed at a:
 - a mid-ocean ridge.
 - b subduction zone.
- 4 Discuss why the discovery of subduction was important for the development of the theory of plate tectonics.
- 5 Select one of the key pieces of evidence that supports the theory of plate tectonics. Evaluate why it is critical to the understanding of plate tectonics.

Nature and development of science

- 1 Identify four different observations made by scientists that support the theory of plate tectonics.
- 2 Describe the importance of collaboration in the development of the theory of plate tectonics.
- 3 Explain why Wegener's theory of continental drift was not supported by the scientific community at the time.
- 4 Discuss how Marie Tharp's work contributed to the development of the theory of plate tectonics.

- 5 a Analyse reasons why Marie Tharp was not taken seriously when she first presented her findings to others.
- b Explain how Tharp's collaboration with another scientist helped to make her evidence stronger.

Evaluating

p. 249

Read through Investigation 5.2 on page 329 before answering the questions below.

- 1 Identify a step or steps in the method where an error could impact the data collected.
- 2 Describe the error in the step you selected in Question 1, and describe how you could minimise its impact on the data.
- 3 Use your understanding to explain how this model can be used to represent the movement of tectonic plates.

Key idea: Stability and change

Use Investigation 5.2 as a basis to create a scaled model that shows how Australia separated from Antarctica. Conduct research to find out when the separation occurred and how fast the continents are moving apart.

Success criteria

- I can explain the theory of plate tectonics.
- I can outline some of the evidence that was used to support the theory of plate tectonics.

5.3 ▶ What causes tectonic plates to move?

Learning intention

At the end of this lesson, I will be able to describe how tectonic plates interact with each other and describe some of the forces that move them.

Key terms

convergent boundary: where two tectonic plates are moving towards each other and colliding

divergent boundary: where two tectonic plates are moving away from one another

transform boundary: where two tectonic plates slide past each other

Investigation 5.3A

Modelling slab pull, p. 331

Investigation 5.3B

Observing convection currents, p. 332

Key idea: Stability and change

As tectonic plates move on the asthenosphere, they slowly transform Earth's surface. We can see particular types of geological features where the plates interact.

Three factors cause the tectonic plates to move. Gravity pulls cold, dense subducting plates down into the mantle, pulling newly formed lithosphere away at mid-ocean ridges. The push of new crust being formed at mid-ocean ridges also moves the plates. Convection currents in the asthenosphere bring hot, low-density rock up towards the crust.

Plates collide at convergent boundaries

Convergent boundaries (or destructive boundaries) are where two plates move towards each other and collide (see Figure 5.13a). The plate that is denser, usually older oceanic crust, subducts underneath the other. If two continental plates collide, the crust buckles and pushes together to form fold mountains. The Himalayas are an example of a mountain range that formed when two plates collided. Because both plates are made of continental crust (which is relatively light and thick), neither plate could sink beneath the other easily. Instead, the crust crumpled, folded and was forced upwards, creating the Himalayan mountain range.

Figure 5.12: The Himalayan mountain range formed when the Indian and Eurasian tectonic plates collided and pushed the land upwards.



Plates separate at divergent boundaries

Divergent boundaries (or constructive boundaries) are where two plates move apart (see Figure 5.13b). Magma rises up in the gap between the plates and solidifies to form new lithosphere. This forms a mid-ocean ridge. When this happens on a continent, it forms a rift valley and volcanoes.

Plates slide past at transform boundaries

Transform boundaries (or conservative boundaries) are where two plates slide past each other (see Figure 5.13c). This causes a break in Earth's surface called a fault. As the plates slowly move, they cause earthquakes; however, usually lithosphere is neither created nor destroyed.

Figure 5.13a: Convergent plate boundary

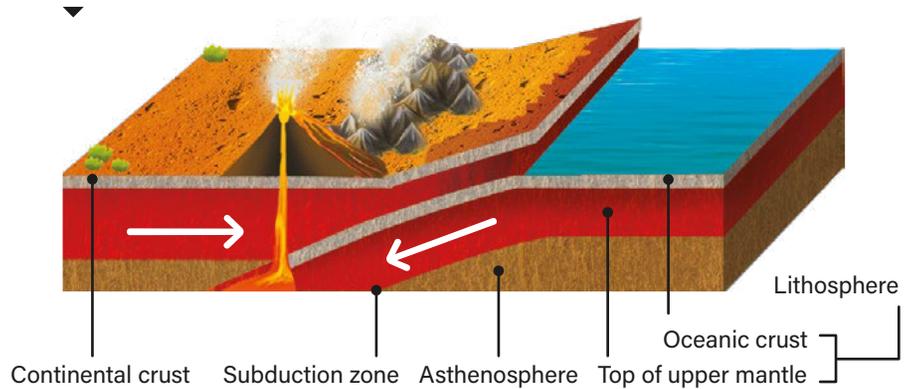


Figure 5.13b: Divergent plate boundary

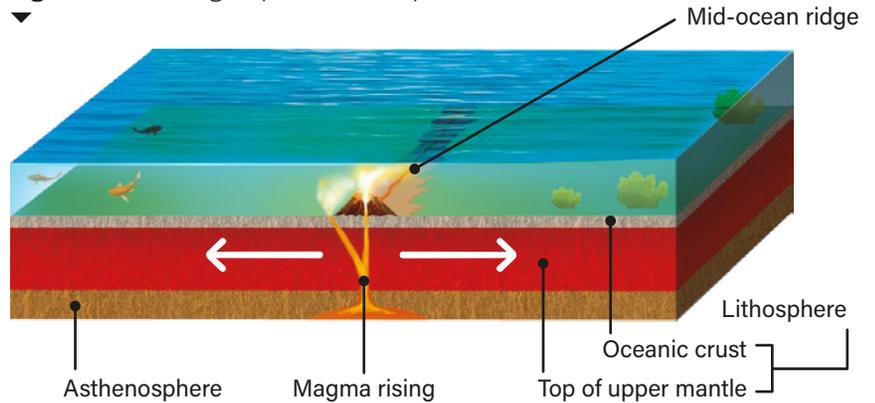
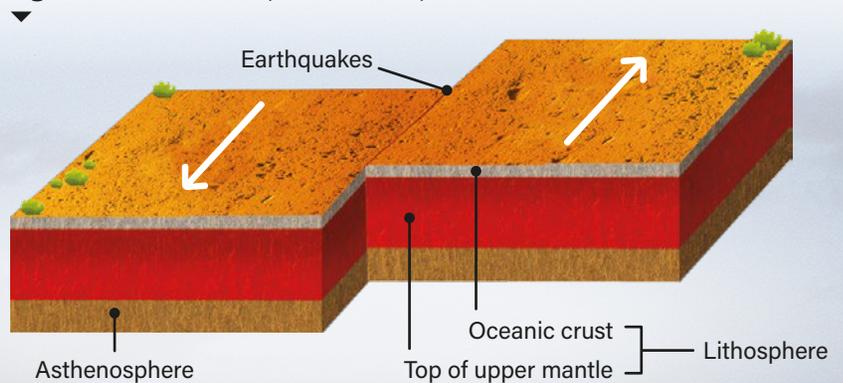


Figure 5.13c: Transform plate boundary



Big plates can pull each other down

When a denser plate moves under another plate (subduction) at a convergent plate boundary, it will start to pull the rest of the plate along with it. This is known as slab pull (see Figure 5.14a). Scientists think slab pull is the major cause of tectonic plate movement. Because a subducting plate is cooler and denser than the warmer mantle, gravity causes it to sink towards Earth's core, pulling the rest of the plate along behind it. Plates with long subduction zones often move faster than plates with shorter subduction zones.

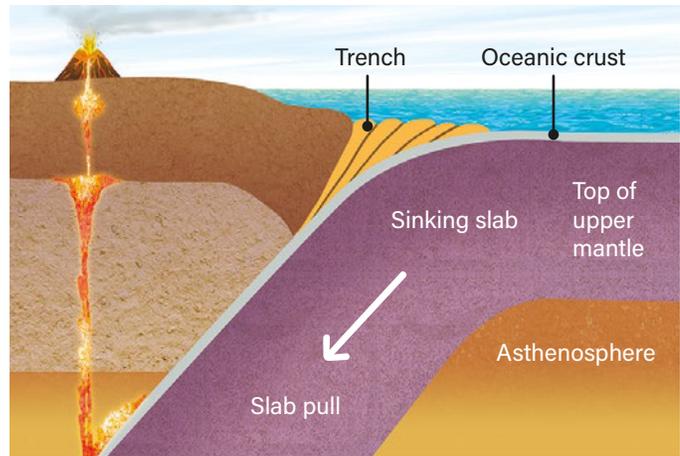
Ridge push is caused by gravity

Ridge push happens at mid-ocean ridges. When magma rises up at a mid-ocean ridge, it forms new lithosphere. This new lithosphere sits higher than the old one and so gravity causes it to slide downhill, pushing the old lithosphere in front of it. This push helps to move the tectonic plate along, away from the mid-ocean ridge towards the subduction zones (see Figure 5.14b).

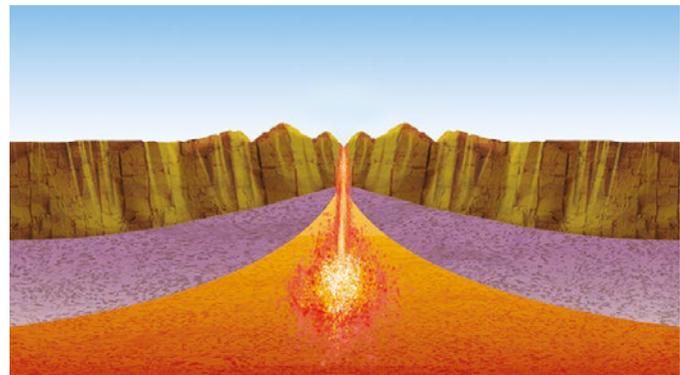
Convection currents help to drag tectonic plates along

Convection is a way of transferring heat. Rock in the asthenosphere moves slowly in convection currents formed by hot rock near the core rising up, cooling and falling back down again. This brings molten material up to the mid-ocean ridges. As the rock in the asthenosphere slowly moves, it drags the plates along, moving them out and away from the mid-ocean ridges towards the subduction zones (see Figure 5.15).

▼ **Figure 5.14a:** Slab pull



▼ **Figure 5.14b:** Ridge push happens when hot magma rises up to form new lithosphere, creating a slope. Gravity causes the tectonic plate to slide down this slope, away from the ridge.



▼ **Figure 5.15:** Convection currents bring molten rock up to mid-ocean ridges. This forms new lithosphere, which slides down due to gravity towards subduction zones.

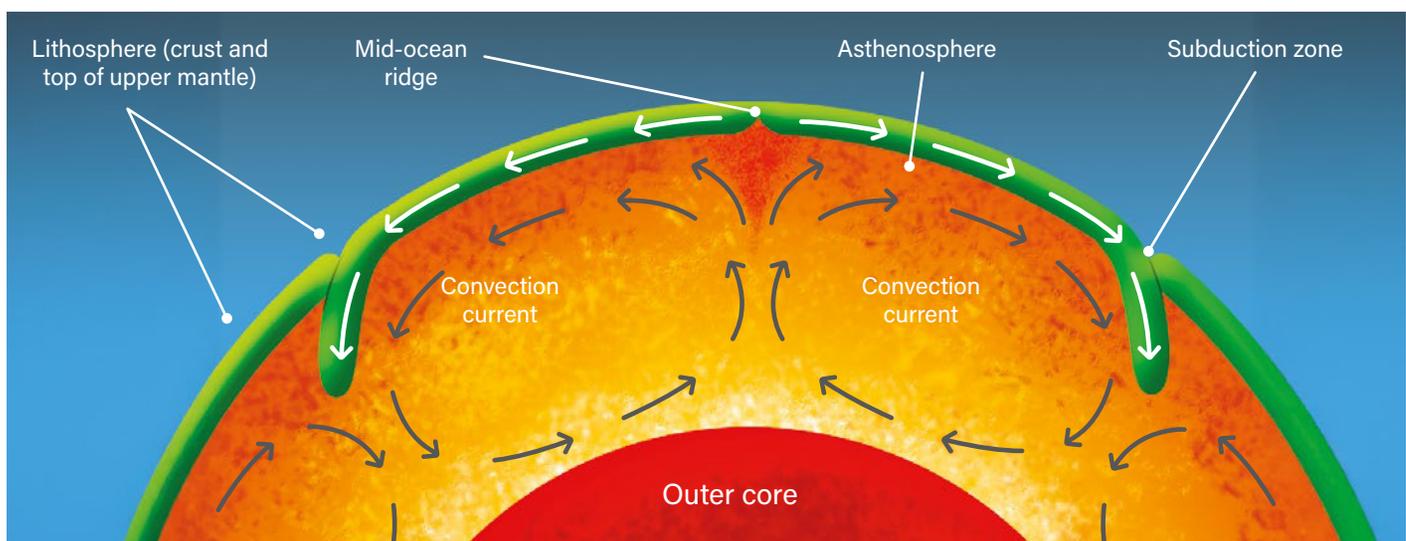
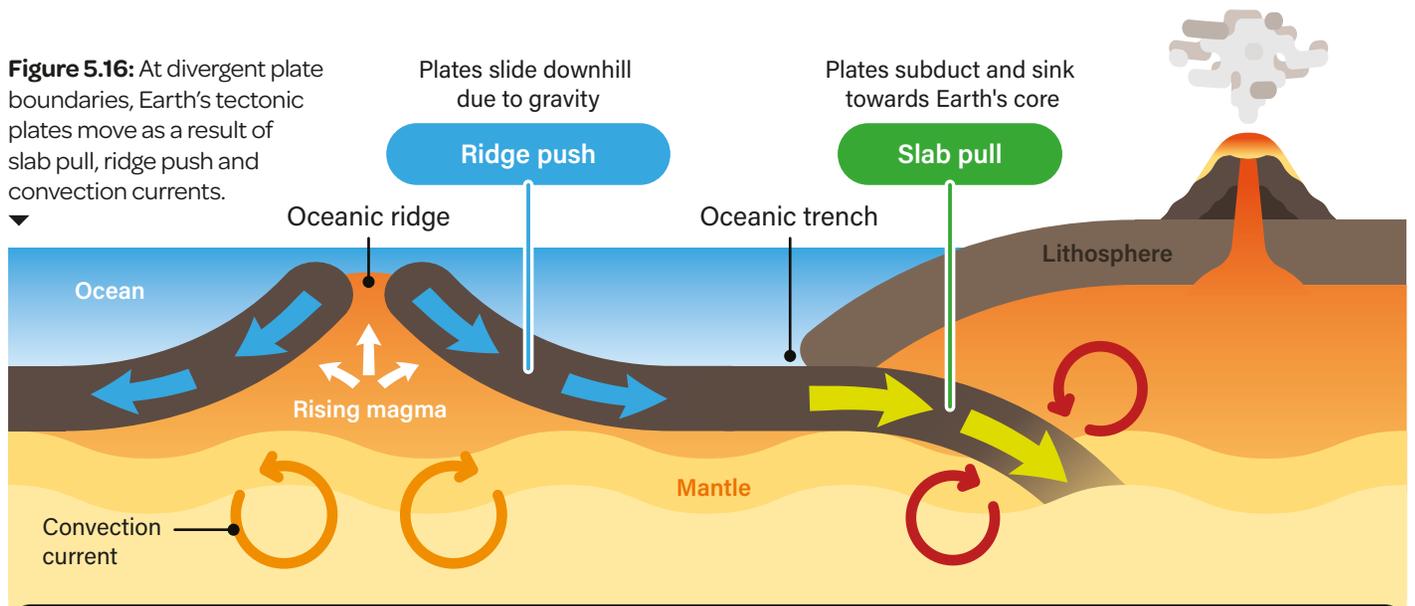


Figure 5.16: At divergent plate boundaries, Earth's tectonic plates move as a result of slab pull, ridge push and convection currents.



Learning Ladder

Plate tectonics

- 1 Identify a geological feature that could be observed in the landscape at a:
 - a convergent boundary.
 - b divergent boundary.
 - c transform boundary.
- 2 Construct simple diagrams that illustrate how two tectonic plates interact at a:
 - a convergent boundary.
 - b divergent boundary.
 - c transform boundary.
- 3 Explain how the following factors cause tectonic plates to move:
 - a Slab pull
 - b Ridge push
 - c Convection currents

Nature and development of science

- 1 Select the best option below.
The idea of slab pull helps to explain:
 - A how two tectonic plates move apart.
 - B how two tectonic plates can slide past each other.
 - C how one tectonic plate can subduct underneath another.
- 2 Geophysicists use various techniques to make measurements underneath Earth's surface. Suggest how geophysicists could collaborate with volcanologists to better understand volcanoes along plate boundaries.
- 3 Before the discovery of plate boundaries, it was thought that continents could not move or drift. Discuss how knowing about the different types of plate boundaries helps us to understand how continents can move.

Planning and conducting

p. 236

Read through Investigation 5.3B on page 332 before answering the questions below.

- 1 Draw a labelled scientific diagram of the equipment you need for this investigation.
- 2
 - a Identify two hazards that you will need to consider during this investigation.
 - b Describe what equipment or techniques you would use to minimise risks.
- 3 Imagine you were to investigate how different temperatures impact convection currents. Identify the:
 - a independent variable.
 - b dependent variable.
 - c controlled variables.
- 4 Construct a results table that would allow you to collect precise data for the investigation you imagined in Question 3.
- 5 Write a method for the investigation in Questions 3 and 4. Make sure you include how to minimise or control any risks or hazards.

Key idea: Stability and change

- a Australia is moving northward at a rate of 10 centimetres a year. Predict what the landforms to the north of the continent would look like in 250 million years. Justify your response.
- b How would the distance between Australia and Antarctica change in 250 million years? Justify your response.

Success criteria

- I can describe the three types of movement that can happen at tectonic plate boundaries.
- I can describe how tectonic plates move.
- I can describe some forces that move tectonic plates.

5.4 ▶ Earthquakes

Learning intention

At the end of this lesson, I will be able to describe how earthquakes occur and how patterns of earthquake activity relate to plate tectonic boundaries.

Key terms

epicentre: the point on Earth's surface directly above the focus of an earthquake

fault: a break or an area of breaks between two blocks of rock

focus: the origin of an earthquake

intensity: a measure of the amount of destruction caused by an earthquake

intraplate earthquake: an earthquake that takes place in the middle of tectonic plates

magnitude: a measure of the energy released by an earthquake

seismic wave: a wave of energy that passes through Earth's layers and is caused by an earthquake

seismometer: a scientific instrument that detects seismic waves

Investigation 5.4

Slinky waves, p. 333

Key idea: Stability and change

Earthquakes are caused by a build-up of pressure and the release of energy in Earth's crust. Most earthquakes happen along the boundaries of the tectonic plates, but they can also happen within a plate. A **fault** is the name given to a part of Earth's surface where blocks of rock slide past each other. Faults can be as large as a tectonic plate boundary or much smaller.

Earthquakes happen when tectonic plates move

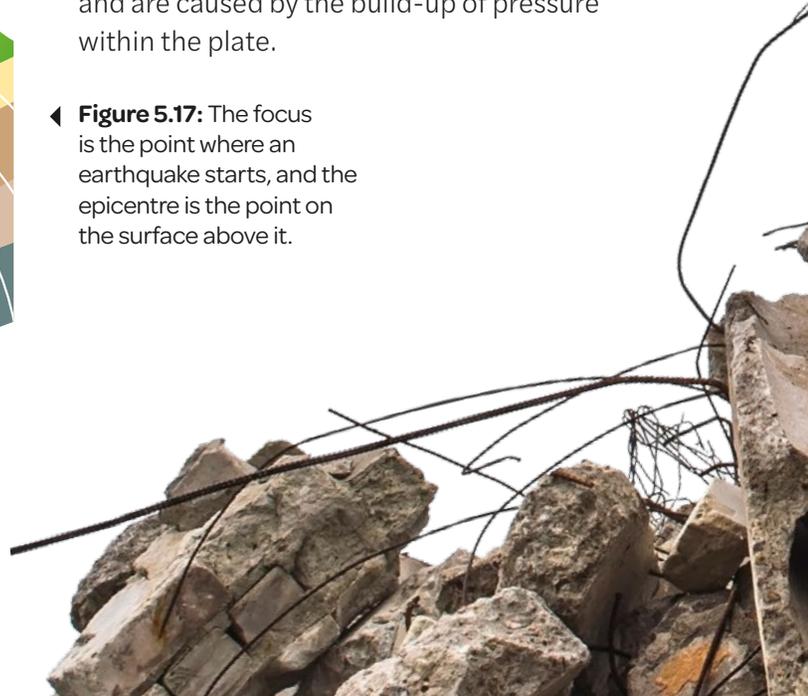
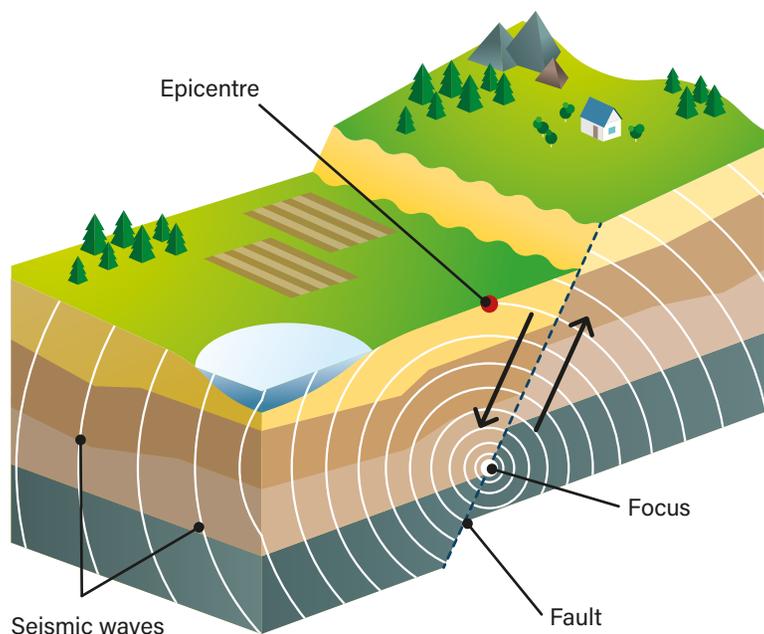
Blocks of rocks do not slide smoothly past each other. They catch and lock together, almost like Velcro. As they catch, pressure builds up until the rock is forced to move, releasing energy. The energy passes through Earth as **seismic waves** that move and shake the crust. This is an earthquake.

The point where an earthquake starts is called the **focus**. This is where the pressure has built up and been released, often causing rocks to rupture (break) and move along the fault. The point on the surface directly above the focus is called the **epicentre**.

Epicentres are usually located along plate boundaries because this is where most movement happens. Shallow earthquakes happen at divergent (constructive) boundaries as the plates move apart. They also happen at transform boundaries because the plates are sliding past each other. Most earthquakes occur at convergent (destructive) boundaries where plates collide. The deepest earthquakes happen at subduction zones because the subducting plate is moving down into the

asthenosphere. Earthquakes that take place within plates are called **intraplate earthquakes**. Intraplate earthquakes happen along fault lines and are caused by the build-up of pressure within the plate.

◀ **Figure 5.17:** The focus is the point where an earthquake starts, and the epicentre is the point on the surface above it.



Earthquakes produce seismic waves

Seismologists are scientists who study earthquakes. They use sensitive equipment called **seismometers** to measure how much and how often Earth's outer layers move as a result of a seismic wave.

There are two main types of seismic wave. Body waves travel through Earth, and surface waves travel around Earth's surface.

There are two main types of body wave – primary (*P*) waves and secondary (*S*) waves. Primary waves travel faster and are longitudinal waves. Secondary waves are transverse waves.

There are also two types of surface waves, known as Rayleigh and Love waves. They can move across the surface in all directions, like a rolling ocean wave. These waves travel more slowly than *P* and *S* waves, but their surface motion causes more destruction (Figure 5.18).

Figure 5.18: Types of seismic waves ▶

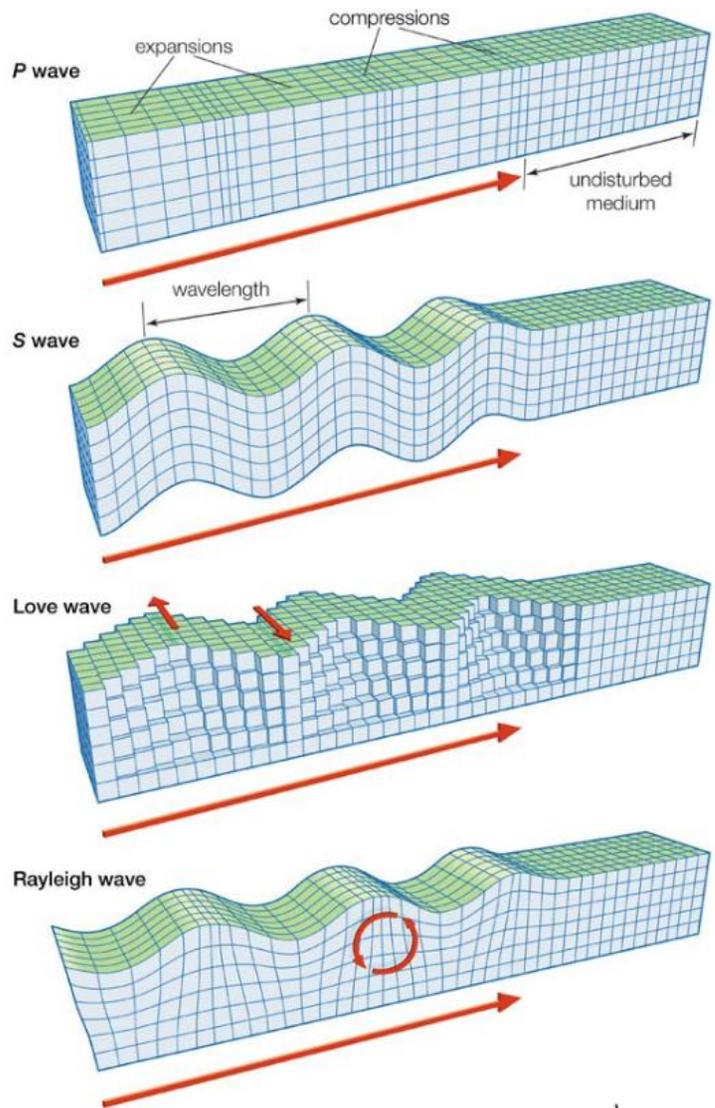


Figure 5.19: The movement of tectonic plates causes a build-up of pressure, which is released as energy in the form of seismic waves that shake Earth's crust. This shaking can cause buildings to crack or collapse altogether. ▼



Earthquakes are measured by magnitude and intensity

Scientists describe the size of the earthquake in terms of its magnitude and intensity.

The **magnitude** of an earthquake depends on how much energy it releases, and is related to the area of the fault that ruptured and how far it moved.

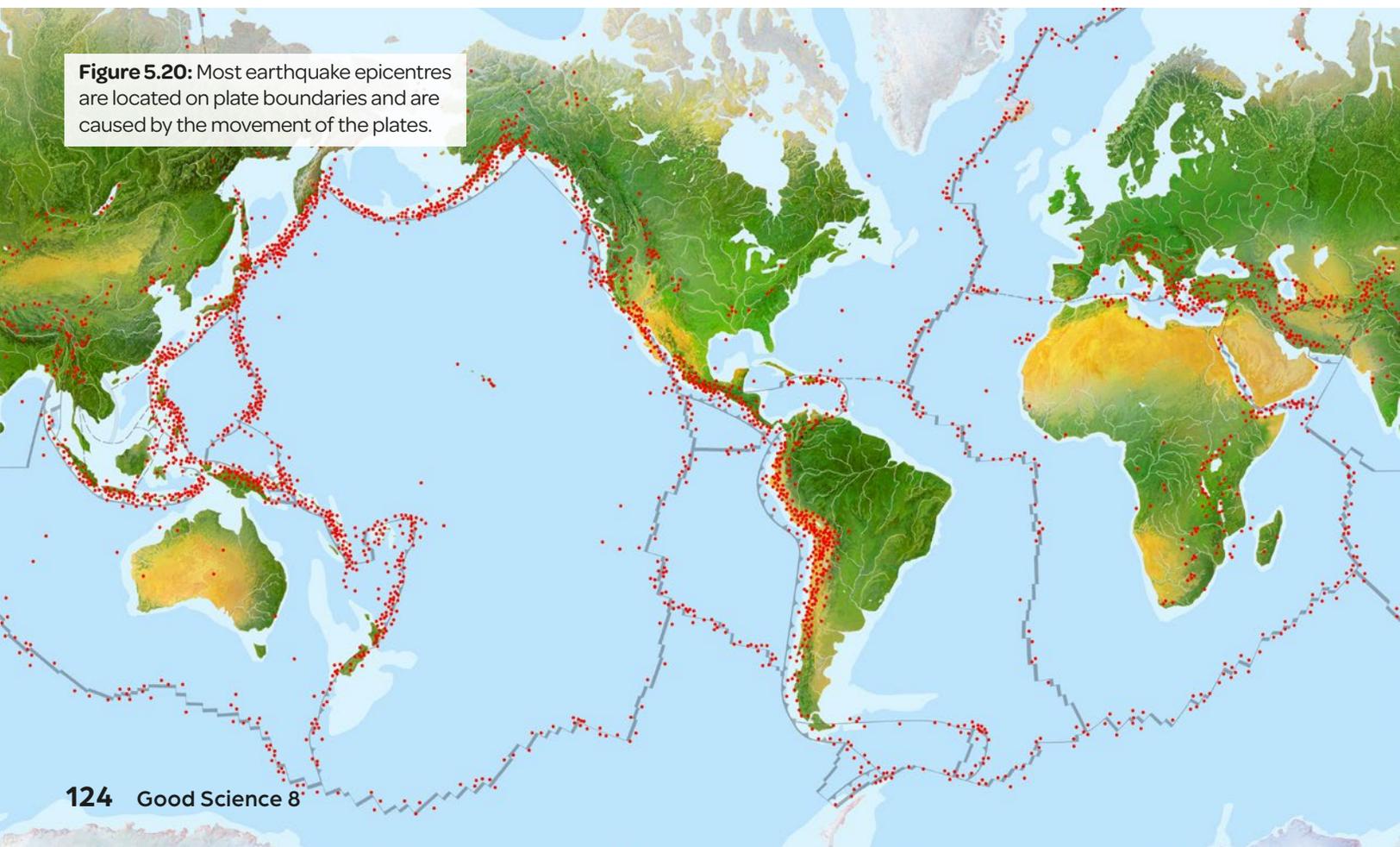
The moment magnitude scale is used to compare earthquakes. On the moment magnitude scale, a magnitude of 10 is equivalent to the energy released by 100 000 atomic bombs. Seismologists now use the moment magnitude scale instead of the Richter scale because it allows them to more accurately compare the sizes of earthquakes all over the world.

An earthquake's **intensity** refers to the amount of damage it causes and is measured by the modified Mercalli intensity scale (Table 5.1). The intensity of an earthquake is influenced by the magnitude of the earthquake, the distance from the epicentre, the local geology, and any buildings and other structures in the area.

Table 5.1: The modified Mercalli intensity scale refers to the amount of damage caused by an earthquake.

Intensity	Shaking	Common observations
I	Not felt	Detected only by instruments
II	Weak	Noticed only by people at rest
III	Weak	Noticed by people indoors. Vibrations similar to a passing truck
IV	Light	Felt by people indoors and some people outdoors. Loose objects disturbed
V	Moderate	Felt by most people. Unstable objects overturned. Pendulum clocks stopped
VI	Strong	Felt by everyone. Slight structural damage
VII	Very strong	Felt by people in vehicles. Damage to poorly designed structures
VIII	Severe	Slight damage to well-designed structures. Much damage to other buildings
IX	Violent	Much damage to substantial structures
X	Extreme	Many buildings destroyed
XI	Disastrous	Few structures left standing
XII	Catastrophic	Total destruction

Figure 5.20: Most earthquake epicentres are located on plate boundaries and are caused by the movement of the plates.



Christchurch earthquake, February 2011

At 12.51 pm on Tuesday, 22 February 2011, a 6.3 magnitude earthquake struck Christchurch, in New Zealand's South Island. The earthquake occurred along a fault that is part of the transform fault boundary between the Australian and Pacific plates. The epicentre was 10 kilometres west of the city and the focus was 5 kilometres deep.

Although the shaking only lasted 10 seconds, the earthquake caused considerable damage to the city and 185 people lost their lives. More than half of the buildings in the central business district were severely damaged. Most of these buildings have since been rebuilt.

To ensure the city is more resilient in the future, building regulations have been updated so that new structures take advantage of modern technology. This includes ensuring that building foundations incorporate earthquake bearings, which allow the building to move along with the earth during a tremor. Many components are now made of ductile steel, which allows the building to flex, but is also easily replaceable if a structure is damaged during an earthquake.



Figure 5.21: This building in central Christchurch was severely damaged in the 2011 earthquake.

Learning Ladder

Plate tectonics

- 1 Identify where most earthquakes happen.
- 2 Describe how an earthquake happens.
- 3 Earthquakes are much more common near convergent boundaries. Propose and explain why.
- 4 Discuss why Australia has fewer earthquakes than New Zealand, in terms of tectonic activity.
- 5 Evaluate if the global pattern of earthquakes is evidence for the theory of plate tectonics.

Use and influence of science

- 1 Complete the sentence below.
_____ refers to the energy released by earthquakes and is used to compare them.
- 2 Describe why the modified Mercalli intensity scale is useful for describing earthquakes.
- 3 Explain why a high-magnitude earthquake in an unpopulated area could have a lower value on the intensity scale than a lower magnitude earthquake in a populated area.

Planning and conducting

p. 236

Imagine you want to conduct an investigation to model how construction material affects how long a building can withstand an earthquake.

- 1 Propose the materials and equipment to be used.
- 2 **a** Identify two potential hazards when using the materials and equipment proposed in Question 1.
b Describe how you could mitigate these risks.
- 3 For your investigation, identify the:
a independent variable.
b dependent variable.
c at least two controlled variables.
- 4 Describe how you would gather your results. *Hint:* Think about what you could measure and/or record.
- 5 Use your answers to Questions 1–4 to help you write an aim and a detailed method for your investigation.

Key idea: Stability and change

Research five large earthquakes and plot their locations on a map of tectonic plate boundaries. Discuss what the locations have in common and describe how the landscape was changed.

Success criteria

- I can explain how earthquakes occur.
- I can describe the link between the location of earthquakes and plate boundaries.

5.5 ▶ Volcanoes

Learning intention

At the end of this lesson, I will be able to describe how volcanoes are formed and how their location relates to plate tectonic boundaries.

Key terms

hotspot (shield) volcano: a volcano formed by magma upwelling underneath a tectonic plate

igneous rock: rock that has solidified from lava or magma

lava: molten (melted) rock above Earth's surface

magma: molten (melted) rock under Earth's surface

strato volcano: a volcano formed at a subduction zone

volcano: a point in Earth's crust where lava erupts

Investigation 5.5A

Viscosity of lava, p. 334

Investigation 5.5B

Wax volcano, p. 335

Key idea: Stability and change

Figure 5.22: A fissure eruption at Iceland's Eyjafjallajökull volcano. This volcano has formed as the North American and European plates move apart.

A **volcano** occurs where molten rock erupts at Earth's surface. Most volcanoes occur along the boundaries of tectonic plates, which helps to explain how they are formed and how they behave. Volcanoes along diverging boundaries have runny lava that spreads out over large areas. Volcanoes formed along subduction zones have thicker lava and tend to be more explosive. Hotspot (shield) volcanoes are formed in the middle of a plate, rather than at a boundary.

Some volcanoes form at divergent plate boundaries

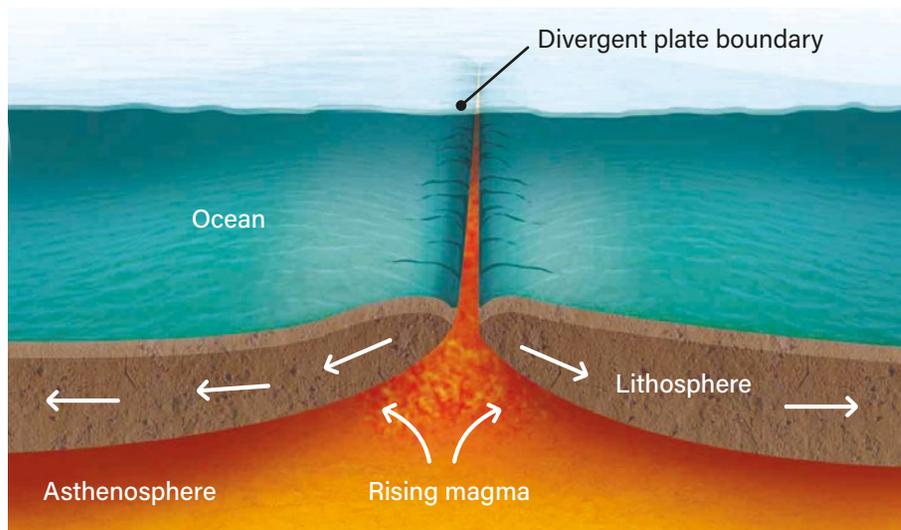
At divergent plate boundaries, volcanoes form when **magma** rises to fill the gap between the two diverging plates.

Most volcanoes on divergent plate boundaries form as fissure volcanoes – long fractures in the crust from which the **lava** erupts – and can be many kilometres long. Because the lava has come from the asthenosphere, it contains a lot of dark minerals and is very hot and runny, so it spreads out over large areas. When it cools and solidifies, the lava forms an **igneous rock** called basalt (see Figure 5.23).



Figure 5.23: Basalt is an igneous rock that is formed from the fast cooling of lava from volcanoes at divergent boundaries. It makes up oceanic crust.

Figure 5.24: Formation of a volcano ▶ on a divergent plate boundary under the ocean. As magma rises up in the asthenosphere, it forms a fissure volcano many kilometres long.



Volcano arcs form at subduction zones

Volcanoes also form in chains known as arcs along the length of subduction zones. Subduction zone volcanoes erupt violently due to the pressure of gases moving up to the surface. Because the lava is sticky, it does not spread very far. Instead, volcanoes build up with steep sides.

Volcanoes along subduction zones are known as **strato volcanoes**. When it cools quickly, magma from this type of volcano can form rhyolite, a fine-grained igneous rock with a high silica content.



▲ **Figure 5.25:** Strato volcanoes are made of alternating layers of lava and ash. Hotspot volcanoes are made of layers of solidified lava.

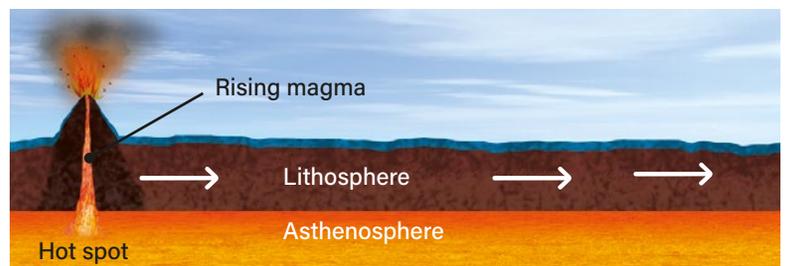
Some volcanoes form in the middle of plates

Some volcanoes are not on plate boundaries but are in the middle of the tectonic plates. These volcanoes are formed when there is an upwelling of magma (a hot spot) in a single location, so they are known as **hotspot (shield) volcanoes**. The lava that erupts out of hotspot volcanoes is similar to that of volcanoes at divergent boundaries because it comes from the asthenosphere. It is made of dark minerals, is very runny and forms the igneous rock basalt when it solidifies. The lava spreads out over large areas and over time forms volcanoes that are wide at the base compared to their height.

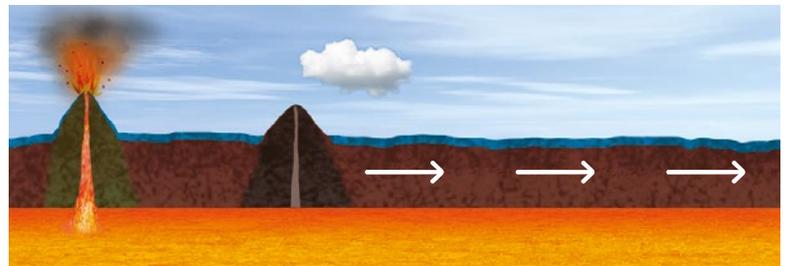
The hot spot in the mantle does not move, but the tectonic plates do. As the plates move, new volcanoes form in a chain (see Figure 5.26). Unlike volcanoes that form along a subduction zone, only the volcano over the hot spot is active and erupts. The volcanoes that have moved away from the hot spot no longer have a magma source and so are said to be extinct.

Figure 5.26: Steps in the formation of a volcanic island chain as a result of hotspot volcanism

- 1 A hot spot breaks through the lithosphere and a volcanic island forms.



- 2 The crustal plate is constantly moving, so the island eventually moves off the hot spot. This makes room for a second volcanic island.



- 3 More islands form as the crustal plate keeps moving over the hot spot.



Volcanoes make new landforms

We often think of volcanoes as destructive, but they can result in the formation of major landforms such as islands. The Hawaiian Islands and Galapagos Islands have been formed by hotspot volcanism, and the positions of the islands in the chain can provide evidence for the direction and speed at which the plate is moving. Volcanoes in eastern Australia are part of a chain of hotspot volcanoes that formed as the continent moved north away from Antarctica. The oldest volcanoes are in Queensland, and the youngest is Mt Gambier in South Australia, which was last active about 10 000 years ago.

Figure 5.27: Volcanoes form at the boundaries between Earth's tectonic plates.

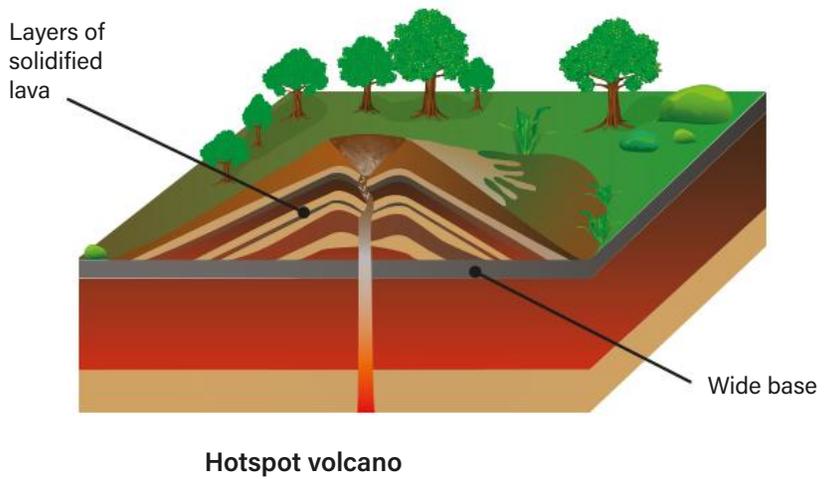
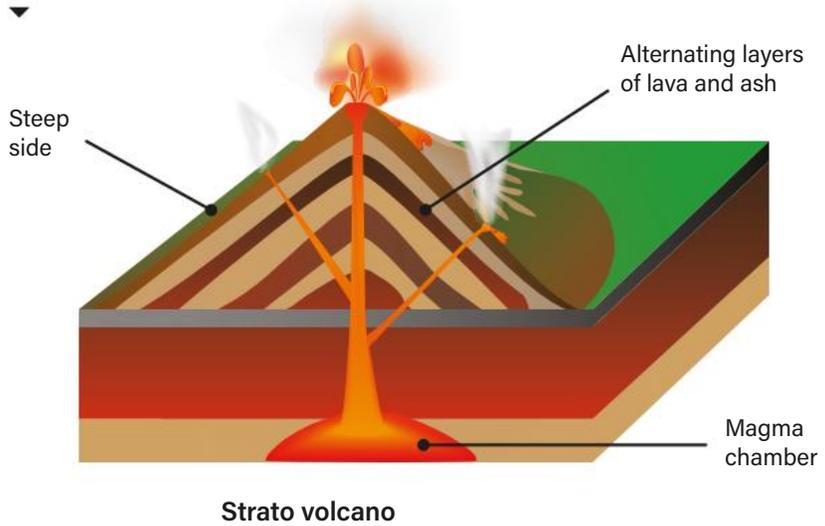
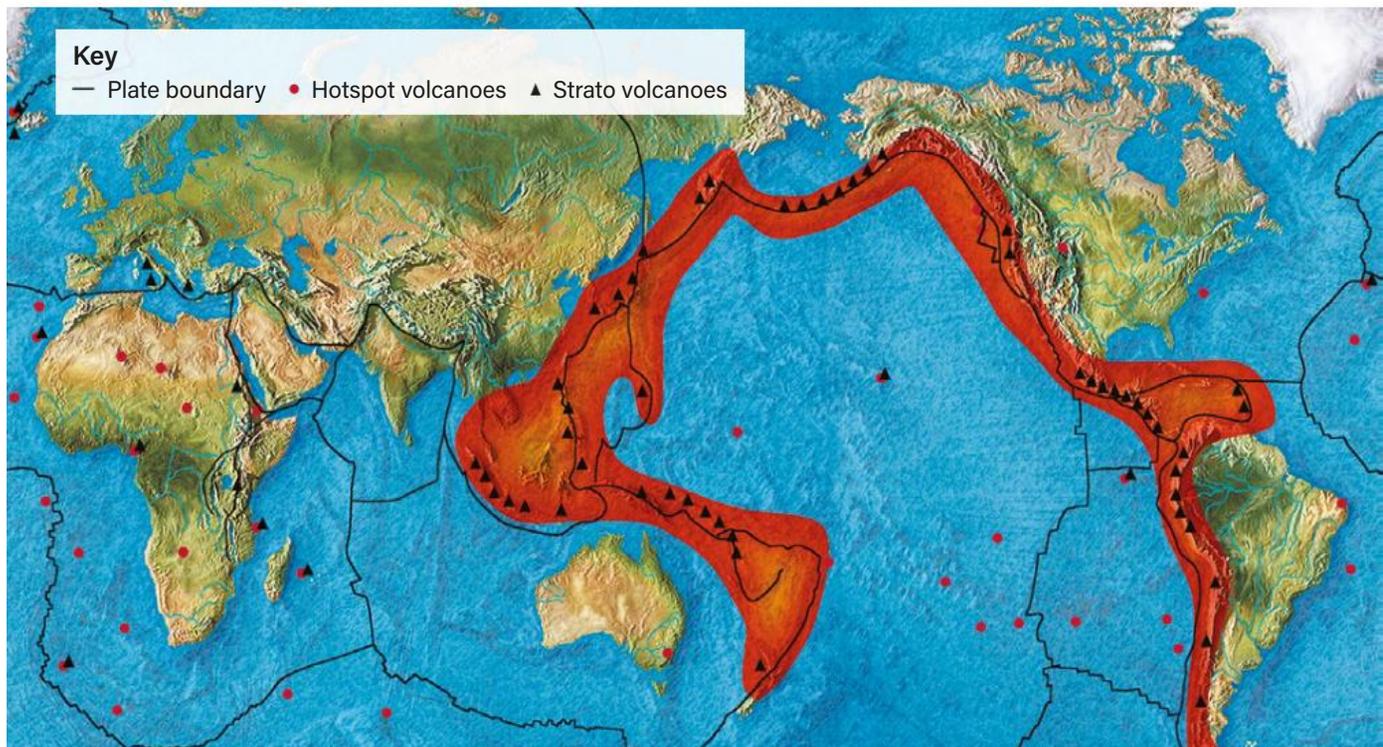


Figure 5.28: The Ring of Fire is a chain of volcanoes around the north, east and western edges of the Pacific Ocean.



Living with volcanoes

Hazards caused by a volcanic eruption can include:

- lava flows that can cover vegetation and damage infrastructure
- ash clouds in the atmosphere that can damage aircraft engines, block out sunlight and cause acid rain
- pyroclastic flows (superheated gas and ash) that move very quickly (100–700 km/hour), destroying everything in their path
- landslides and lahars (mudslides caused when ash mixes with water) that can cover vegetation and damage infrastructure.

The lava and ash that is released during a volcanic eruption will weather over time to create highly fertile soils. This means that people will choose to live around an active volcano even though there is the risk of eruption, because the crops they plant will have very high yields. Other benefits of living around an active volcano include being able to harness geothermal energy as well as income from tourism. In many countries, volcanologists will monitor volcanoes for signs of eruption so that people can be warned and evacuate to safety before an eruption takes place.



Figure 5.29: Mt Merapi is the most active volcano in Indonesia. It is located 28 kilometres from Yogyakarta city, with a population of 1.4 million people, and is surrounded by villages and farmland.

Learning Ladder

Plate tectonics

- 1 From the following, identify the best definition of a volcano.
A A cone-shaped mountain
B Where molten rock erupts at Earth's surface
C Where lava reaches the surface with an explosion
D A long fissure under the ocean
- 2 Copy and complete the following sentences.
a A _____ volcano forms when there is an upwelling of _____ in the _____ of a tectonic plate.
b _____ volcanoes form in chains along _____ zones formed at _____ boundaries.
- 3 Explain how volcanoes form at:
a divergent boundaries.
b subduction zones.
c hot spots.
- 4 Compare and contrast a chain of islands formed by a hot spot with a chain of islands formed by a subduction zone.
- 5 You observe some volcanoes on a continent. Explain what evidence you would need to look for to determine how they were formed. Justify your reasoning.

Use and influence of science

- 1 Identify the hazards that volcanoes pose to people who live nearby.
- 2 Propose how knowledge of volcanoes benefits society.

Evaluating

p. 249

Read through Investigation 5.5A on page 334, then answer the questions below.

- 1 Identify where an error could be introduced in the method.
- 2 **a** Describe the type of error you identified in Question 1.
b Describe how the equipment or techniques could be modified to minimise the impact of this error.

Key idea: Stability and change

Volcanoes can be stable for long periods, but may become unstable quickly. Conduct research on an active volcano such as Mt Merapi. Construct a poster that explains how it was formed, what type of eruptions it has and its impacts on people. Include a timeline indicating stable periods and when eruptions (changes) have occurred.

Success criteria

- I can describe what a volcano is.
- I can explain the relationship between volcanoes and plate tectonics.

5.6 ▶ Aboriginal and Torres Strait Islander Peoples' accounts of earthquakes and volcanoes

Learning intention

At the end of this lesson, I will be able to understand how First Nations stories can inform Western scientists about the geology of Australia and how they can be accurate accounts of past events.

Key term

Newer Volcanics Province: an area covering roughly 15 000 square kilometres in south-east Australia; the continent's most recent active volcanic area

Key idea: Stability and change

Figure 5.30: Newcastle, NSW, in the aftermath of the 1989 earthquake

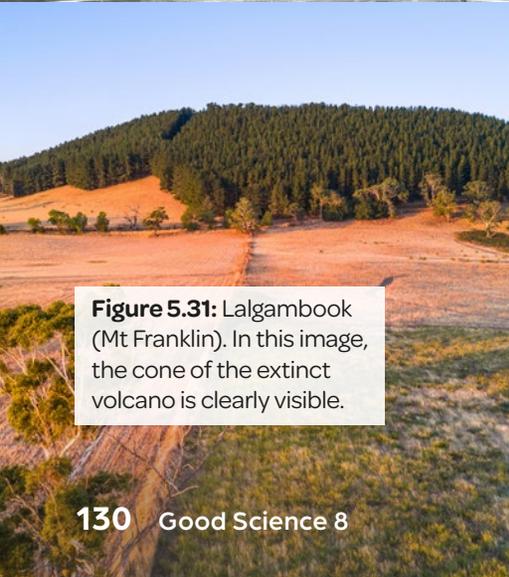


Figure 5.31: Lalgambook (Mt Franklin). In this image, the cone of the extinct volcano is clearly visible.

In geological terms, the continent of Australia is one of the most stable places on Earth. The continent is located at the centre of the Indo–Australian Plate, which means there are relatively few earthquakes, and no active and few dormant volcanoes, on the Australian mainland. Australia does have two active volcanoes in the Australian Antarctic Territory at Heard Island and the nearby McDonald Islands, located 4000 kilometres south-west of Perth.

Australia has earthquakes and volcanoes

The most recent volcanic eruptions on the Australian continent were around 5000 years ago, in what is now South Australia and Victoria. This area of more than 15 000 square kilometres, known as **Newer Volcanics Province**, has more than 400 dormant volcanoes.

The Newer Volcanics Province is thought to consist of hotspot volcanoes, formed when heat was transferred from the upper mantle through a thin spot in the crust. Evidence of this is that the volcanic rock is significantly younger in the southern parts of the Newer Volcanics Province. This is in line with the northern movement of the Indo–Australian Plate at approximately 6.9 centimetres a year.

Although Australia is not on a tectonic plate boundary, it does experience about 100 small earthquakes every year and a large one every few years. In 1989, a large earthquake near Newcastle in New South Wales killed 13 people and damaged more than 50 000 buildings (see Figure 5.30).

Two feuding volcanoes are part of our history

All the volcanoes on the Australian continent are dormant, so there are few First Nations stories of volcanoes. One story is from Dja Dja Wurrung Country in the Central Goldfields region of Victoria. This story explores the relationship between two volcanoes, Tarrengower and Lalgambook. Lalgambook, a young and cheeky volcano, attempted to challenge Tarrengower's power and authority by throwing rocks at him. Tarrengower did not respond but told Lalgambook that he was too weak to hit him with the rocks. Lalgambook got angrier and angrier and threw rocks high into the sky at Tarrengower but was unable to reach him. This caused Lalgambook to completely blow his core.

Lalgambook was named Mt Franklin by the Europeans and is classed as an extinct volcano. It last erupted around 5000 years ago. It is a prominent, conical scoria cone with a deep crater.

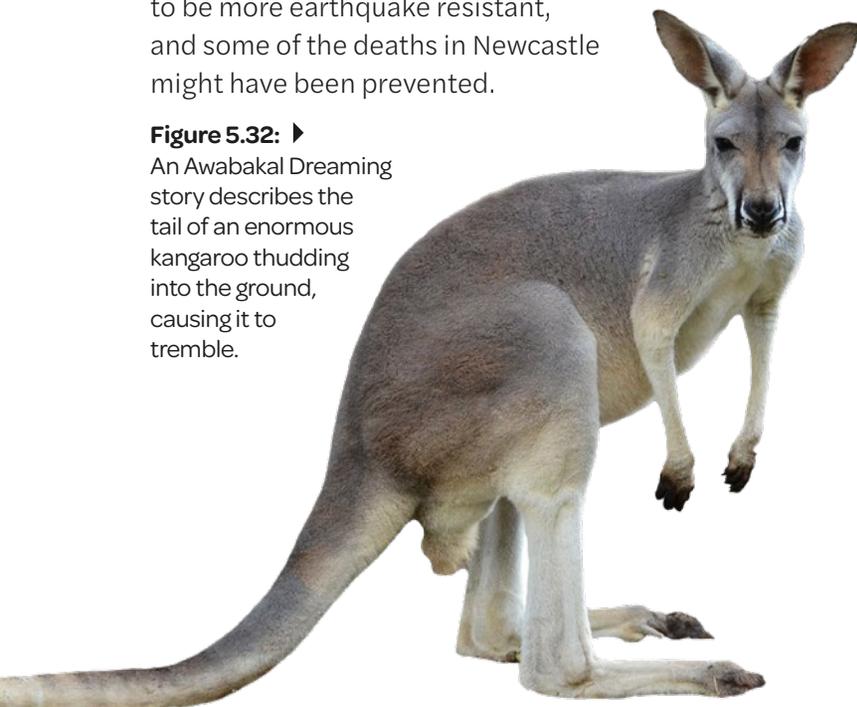
The story of the two feuding volcanoes is important for two main reasons. First, it details a relatively rare phenomenon of two volcanoes that share a magma reserve erupting simultaneously. Second, it is a lesson for young Dja Dja Wurrung People on how to speak and engage with their Elders – that is, to be patient and not be too quick to get angry.

Awabakal Dreaming relates to earthquake activity

The Awabakal Dreaming story relates to earthquake activity on Awabakal Country in the Central Coast region of New South Wales, close to Newcastle. This story describes a giant kangaroo that was chased to Awabakal Country by a group of wallabies after it attacked one of them. The giant kangaroo hid there, and the Dreaming story explains that the tremors that occur are caused by the giant kangaroo's tail hitting the ground.

This story is important because it shows how the Awabakal People have known about earthquakes and have experienced them for many thousands of years. When the Europeans colonised this part of the Australian continent, they had no knowledge of the long history of earthquakes, and so were not prepared for the 1989 Newcastle earthquake. If Western scientists had better understood the First Nations perspective, buildings could have been designed to be more earthquake resistant, and some of the deaths in Newcastle might have been prevented.

Figure 5.32: ▶ An Awabakal Dreaming story describes the tail of an enormous kangaroo thudding into the ground, causing it to tremble.



Learning Ladder

Plate tectonics

- 1 Identify the region in Australia where over 400 dormant volcanoes are located.
- 2 Describe the two types of tectonic activity in the Dja Dja Wurrung and Awabakal Dreaming stories.

Use and influence of science

- 1 Identify one geological feature of the Newer Volcanics Province.
- 2 Examine Figure 5.30. Describe how knowledge of earthquakes informs how buildings are designed and built.
- 3 Explain why the Newer Volcanics Province is considered to be extinct.
- 4 Discuss how the story of the Two Feuding Volcanoes could impact how young people speak to Elders.
- 5 Analyse how Awabakal knowledge of earthquakes could have helped people in the 1989 Newcastle earthquake.

Evaluating

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- 1 Propose an assumption that engineers and builders made when constructing buildings in Newcastle before 1989.
- 2 Describe an error they made.
- 3 Suggest a science-based reason for the Two Feuding Volcanoes erupting at the same time.
- 4 Create an evidence-based argument of how knowing about the Awabakal Dreaming story could have changed building design in Newcastle before 1989.

Key idea: Stability and change

Research the Newer Volcanics Province and find out the following information:

- For how long (approximately) was it an active volcanic area?
- How long has it been dormant?
- List three possible reasons why this area became dormant.

Success criteria

- I can describe how First Nations Dreaming stories can share important scientific knowledge about tectonic activity.
- I can explain how Aboriginal and Torres Strait Islander accounts of tectonic activity can be used in contemporary science practice.

5.7 ▶ Key idea: Stability and change – monitoring our Earth

Learning intention

At the end of this lesson, I will be able to identify the Pacific Ring of Fire and describe how scientists monitor for geological hazards.

Key terms

groundwater: water held underground in porous rock and soil

seismic data: data relating to earthquake waves

tsunami: a sea wave caused by the displacement of water as a result of an earthquake or other disturbance

Key idea: Stability and change

- ▼ **Figure 5.33:** The 2004 Boxing Day Tsunami devastated coastal areas in countries all around the Indian Ocean, including Sri Lanka (shown here), and resulted in the deaths of nearly a quarter of a million people.

Monitoring our Earth is crucial, not only to further our understanding of how it works, but to be able to provide people with information and warnings if they live in a region that could be impacted by a volcanic eruption, earthquake, tsunami – or all three. As the planet changes – whether slowly or rapidly – scientists utilise data gathered from very precise instrumentation on the ground and by satellites to be able to provide up-to-date information.

Monitoring subduction zones

Computer analysis of **seismic data** can help geologists build better models of local geology, such as how plates move at subduction zones. As one plate subducts under another, it causes many earthquakes to occur. Scientists can plot this information to produce a three-dimensional image of the subduction zone. The data can also identify if the plate tends to move down at a steady rate, causing many smaller earthquakes, or if it tends to get stuck and move suddenly, causing fewer but larger earthquakes.

Seismologists can determine patterns and predict the possible magnitudes and intensities of earthquakes in a particular region, but they cannot predict exactly when an earthquake is going to occur.

Tsunami warnings

Tsunamis are fast-moving waves generated from a sudden massive movement of water. Most tsunamis are caused by earthquakes, but they can also be caused by undersea volcanoes or even a meteorite impact. Tsunamis can result in mass destruction and loss of life in populated areas.

Earthquakes that cause tsunamis happen along subduction zones because when one plate moves under during an earthquake, it pushes the other plate upwards suddenly, displacing the water above it.



After the 2004 Boxing Day Tsunami destroyed communities and lives around the Indian Ocean rim, the Australian Government funded the Joint Australian Tsunami Warning System, which uses various technologies to detect tsunamis. The system involves a network of seismic sensors that measure earthquakes and send out warnings when an earthquake occurs that could cause a tsunami.

Deep ocean detection buoys have also been deployed near the subduction zones that surround Australia to monitor sea-level changes. The buoys will send out an alert via satellites if they detect a change in sea level that could have been caused by a tsunami, providing the warning centre with further information.

▼ **Figure 5.34:** A deep ocean detection buoy is deployed in the Tasman Sea to monitor changes in sea levels that may have been caused by a tsunami.



Monitoring volcanoes

Volcanoes usually emit warning signs that they are going to erupt. Volcanologists monitor signs that magma is moving towards the surface, including the detection of small earthquakes, changes to the chemistry of gas emissions and **groundwater**, and even deformation of the ground. Often this monitoring relies on the scientists being close to the volcano and

taking direct samples or observing sensors that have been placed in key locations. Satellites are also used to observe changes on the surface that indicate a volcanic eruption could take place. This is really useful technology that allows volcanologists to monitor remote volcanoes to learn how they change and provide warnings of eruptions.



Figure 5.35: A volcanologist takes a sample of lava from a volcano.

Living on the Pacific Ring of Fire

People who live around the Ring of Fire may be used to volcanoes being significant features of their landscape. They may need to deal with regular earthquakes, and they may even need to be prepared to evacuate the coastline if there is the threat of a tsunami. While for the most part living on the Pacific Ring of Fire can be stable, things can change rapidly. There are many different monitoring systems in place around the Pacific Ocean to help scientists develop a better understanding of how the plates are interacting, as well as to provide early warnings of tsunamis and volcanic eruptions.



Figure 5.38: Mt Etna, in Sicily, is one of the most active volcanoes in the world today. It has erupted several times in recent years, including in 2021 and 2025. Volcanologists monitor the volcano to provide updates and warnings to people who live nearby.

Learning Ladder

Plate tectonics

- 1 Complete the sentence below.
The Pacific Ring of Fire is a ring of _____ around the Pacific _____ caused by _____.
- 2 Distinguish between a normal ocean wave and a tsunami.
- 3 Explain why subduction zones cause the formation of volcanoes and a high number of earthquakes.
- 4 Discuss the distribution of volcanoes around the edge of the Pacific Ocean, relating it to plate boundary types.
- 5 Evaluate the presence of the Pacific Ring of Fire as evidence to support the theory of plate tectonics.

Use and influence of science

- 1 Identify the statements below as true or false. If they are false, rewrite them so that they are true.
 - a The detection of moving magma indicates a volcanic eruption could take place.
 - b Scientists can predict where and when an earthquake will occur.
 - c Tsunami warning systems detect changes in sea level around divergent plate boundaries.
- 2 Describe a benefit of monitoring subduction zones.
- 3 Explain why it is important to monitor the Pacific Ocean for tsunamis.

- 4 Discuss the impact of the 2004 Boxing Day Tsunami on the development of a tsunami warning system for Australia.
- 5 Analyse the importance of being able to effectively communicate scientific warnings of events to people living on the Ring of Fire.

Evaluating

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Scientists were doing a simulation in a pool to test the accuracy of a deep ocean detection buoy to be used to detect tsunami waves.

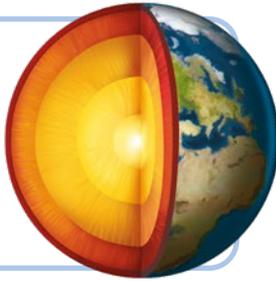
- 1 Which of the following is an assumption for this investigation?
 - A The artificial waves are similar to those of a real tsunami wave.
 - B The wave height detected.
- 2 Describe two types of errors that may occur in the investigation.

Success criteria

- I can describe the Pacific Ring of Fire.
- I can describe some ways that scientists can monitor and provide warnings about volcanoes, earthquakes and tsunamis.

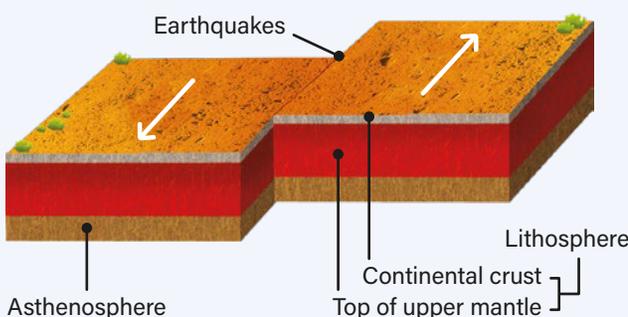
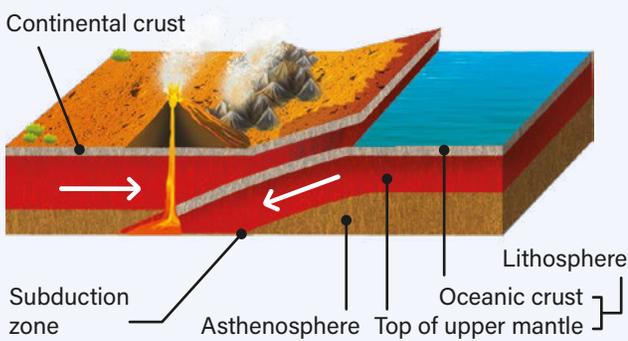
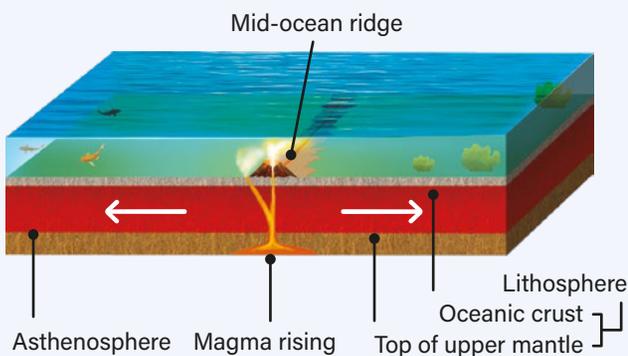
► Summary

- Earth's three main layers are the crust, mantle (upper and lower), and core (inner and outer).
- Earth's atmosphere is a 600-kilometre-thick layer of gas that surrounds the planet.

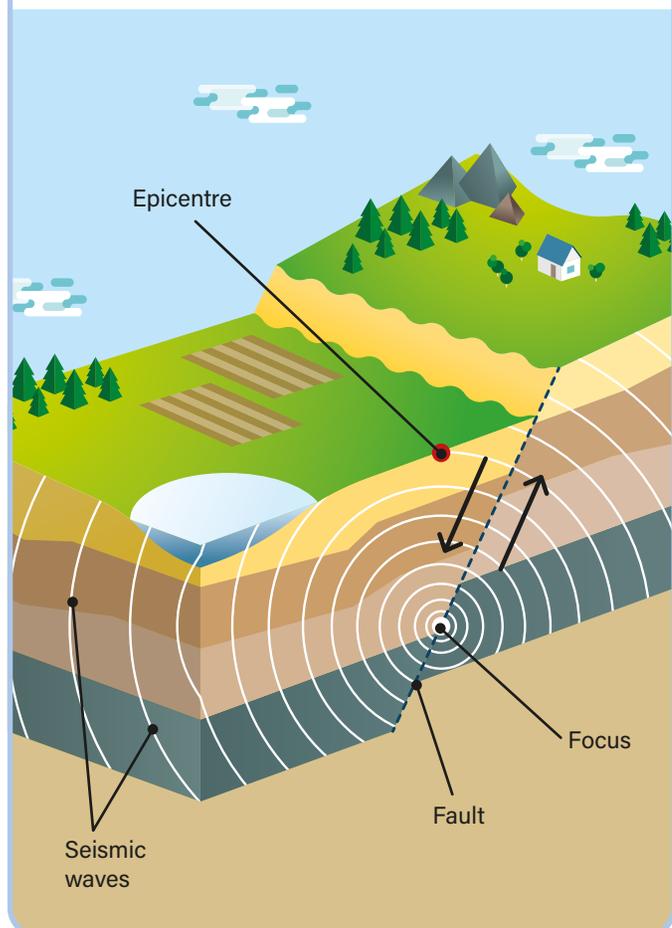


- The **lithosphere** is Earth's rigid, rocky outer zone (the crust and most of the upper mantle).
- The **theory of plate tectonics** states that the lithosphere is divided into more than 15 tectonic plates. Evidence for this theory includes:
 - identical rock and fossil formations on different continents
 - mid-ocean ridges where the sea floor is spreading apart to create new lithosphere
 - subduction zones where old lithosphere is destroyed
 - volcanoes and earthquakes along subduction zones and mid-ocean ridges.

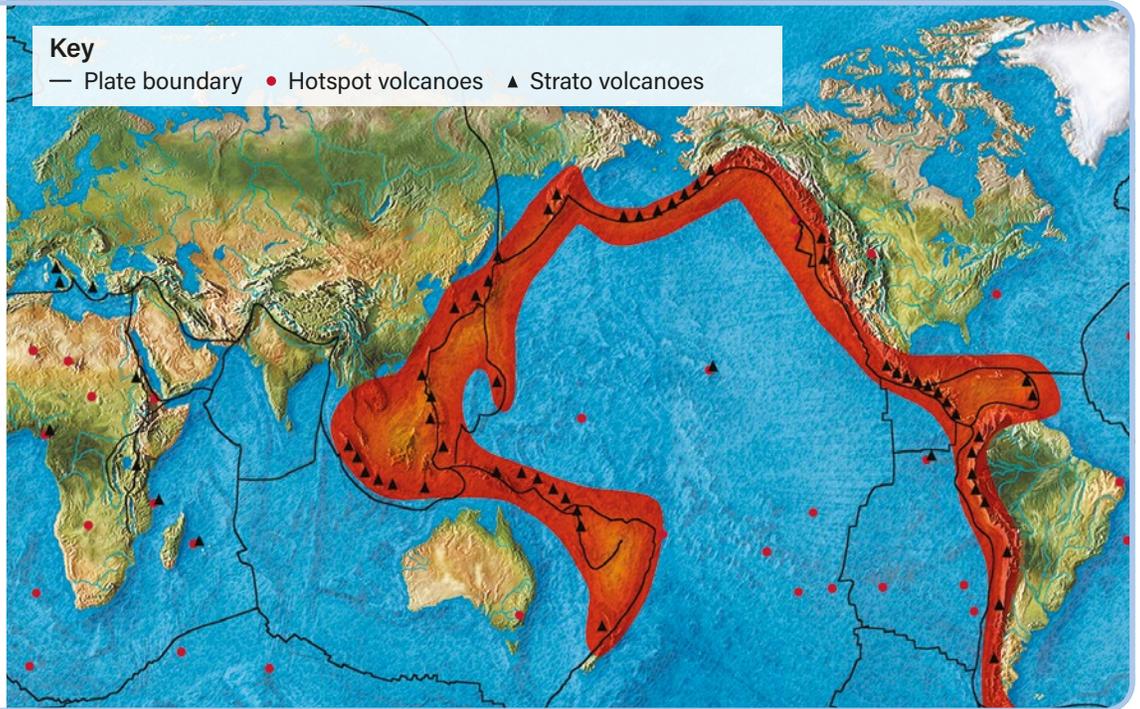
- At divergent boundaries, tectonic plates move apart.
- At convergent boundaries, tectonic plates collide.
- At transform boundaries, tectonic plates slide past each other.



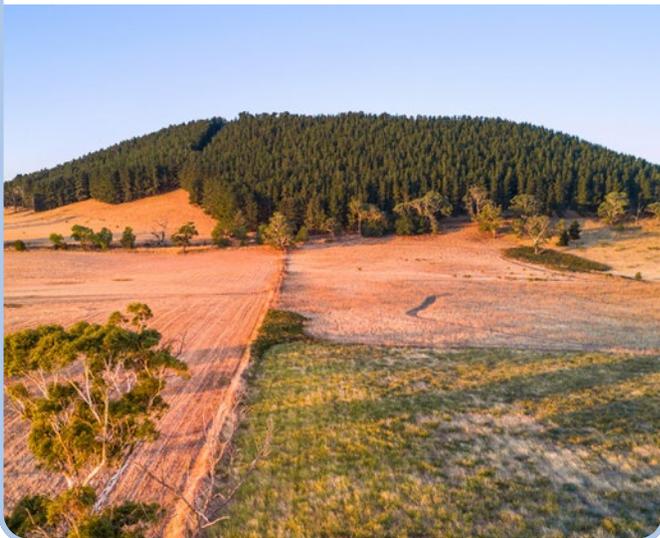
- Earthquakes occur when pressure builds up between tectonic plates and is released as seismic waves.
- Earthquakes usually occur along the boundaries of tectonic plates.



- A volcano occurs where molten rock erupts at Earth's surface.
- Most volcanoes occur along the boundaries of tectonic plates.



- The Australian continent is located in the centre of the Indo-Australian Plate, so there are relatively few earthquakes and no active and few dormant volcanoes.
- The story of Tarrengower and Lalgambook, two feuding volcanoes from Dja Dja Wurrung Country, details the relatively rare phenomenon of two volcanoes that share a magma reserve erupting simultaneously.
- The Awabakal Dreaming story from the NSW Central Coast describes the tail of a giant kangaroo hitting the earth and causing tremors. It indicates that the Awabakal People knew about and experienced earthquakes.



Key idea: Stability and change

- For the most part, life on a tectonic plate boundary is relatively stable; however, things can change quickly.
- Geologists monitor tectonic activity to be able to better understand Earth and to make predictions about volcanoes, tsunamis and earthquakes.



Masterclass

Steps in progression

1

2

Science understanding	Plate tectonics	Identify the geological feature(s) that cause earthquakes.	Describe how the tectonic plates interact along the South Island of New Zealand.
Science as a human endeavour	Nature and development of science	Select the correct response. Constructing a building made of flexible materials such as steel enables it to: A move as the ground moves. B stay rigid during an earthquake.	Describe the importance of collaboration between the Christchurch city council and geologists in planning for future earthquakes.
	Use and influence of science	Propose at least two ways that earthquakes impact the people of New Zealand.	Describe how improving knowledge about earthquakes can impact the local population.
Science inquiry	Planning and conducting	Write a materials list for this investigation: <i>Investigate how soil type affects building movement due to liquefaction by mixing different types of soil with a fixed amount of water in a container, using a model building and shaking.</i>	Construct a risk assessment for the investigation.
	Evaluating	A student measures out soil for their investigation by using three handfuls per container. Identify the error in their method.	Describe the type of error you identified in step 1. Suggest how you could improve the method to limit the effects of errors on the results.

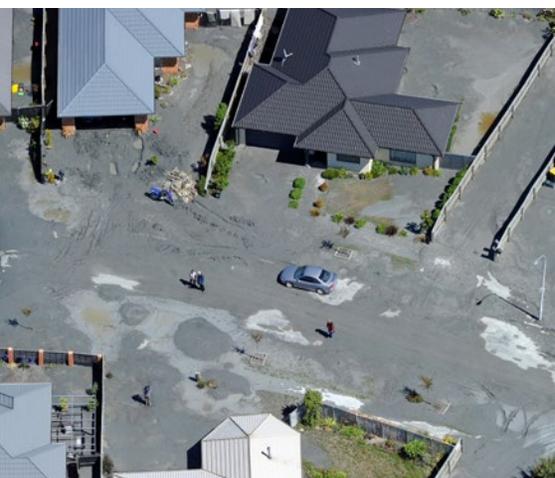


Figure 5.39: A suburban street in Christchurch is covered by silt brought up to the surface due to liquefaction in the February 2011 earthquake.

Liquefaction – an earthquake hazard

When a large earthquake struck the city of Christchurch in New Zealand at 12.51 pm on Tuesday, 22 February 2011, shaking in the central business district (page 125) caused buildings there to collapse. The earthquake's impact in the surrounding suburbs was quite different.

Out in the suburbs, many houses, roads and other infrastructure were damaged due to a phenomenon known as liquefaction. Liquefaction happens when the intense shaking of the earthquake causes soils to act like a liquid rather than a solid. If you have ever wiggled your feet in wet sand at the beach, causing them to sink into the sand, you have experienced a form of liquefaction.

After the 2011 earthquake, the Christchurch city council gathered information on the soils in the region and developed maps to help them determine the risks for different areas. This has allowed the council to determine what types of buildings can be built, in order to reduce damage and destruction from liquefaction in the future.

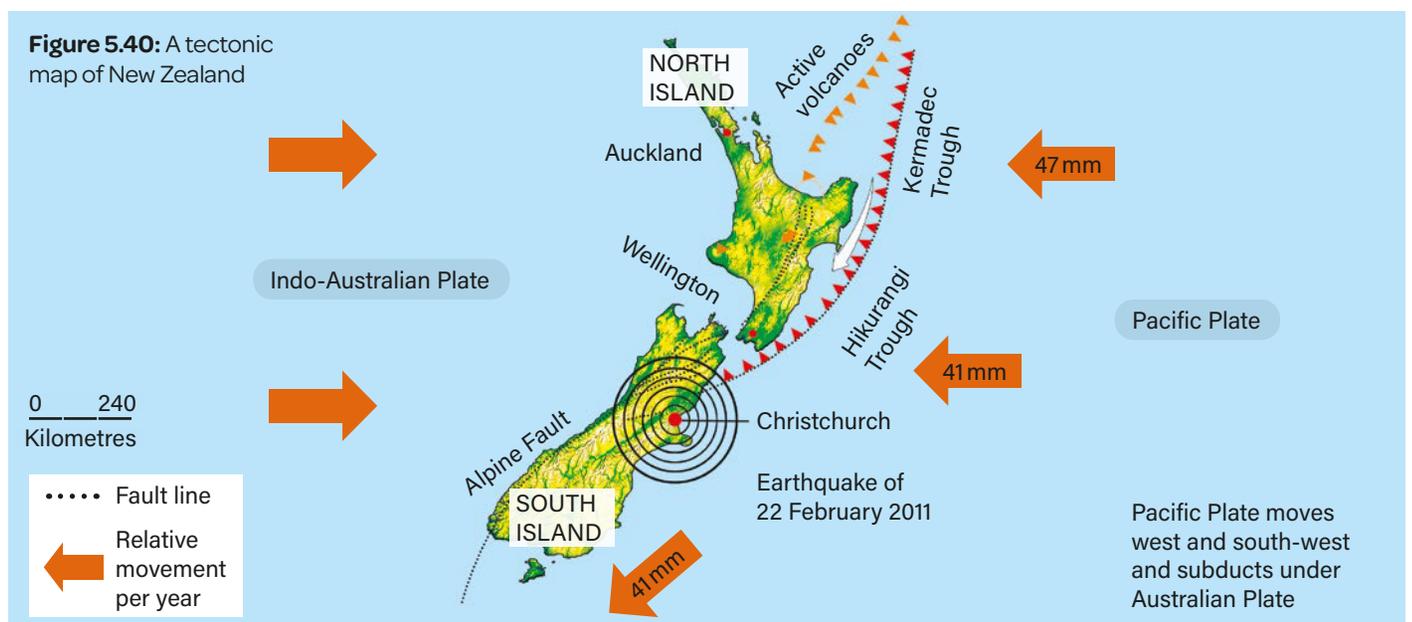
Demonstrate your understanding

3

4

5

<p>Explain why New Zealand is a geologically active country.</p>	<p>Discuss how an earthquake changes Earth's surface, with reference to movement of tectonic plates.</p>	<p>Evaluate how the global pattern of earthquakes supports the theory of plate tectonics.</p>	
<p>Explain the benefit of being able to predict an earthquake.</p>	<p>Discuss the benefits of a map showing the global pattern of earthquakes.</p>	<p>Analyse how engineers, architects and seismologists collaborate to improve earthquake-resistant buildings.</p>	
<p>Propose and explain how buildings collapsing in earthquakes has impacted the development of engineering techniques.</p>	<p>Discuss the impact that preventing people from rebuilding in zones prone to liquefaction would have had on the people of Christchurch.</p>	<p>Research the New Zealand ShakeOut program. Analyse the importance of such education programs in improving the population's response to geological hazards.</p>	
<p>Identify the independent, dependent and controlled variables for the investigation.</p>	<p>Identify the data to be collected for the investigation. Propose tools and techniques you could use to collect the data. Construct a results table to record the data.</p>	<p>Construct a step-by-step method for the investigation.</p>	<p>Science how-to p. 236</p>
<p>Imagine that you found the sandy soil resulted in the largest movement of your building compared to the clay soil. Write an explanation that supports this finding.</p>	<p>The Christchurch city council prevented people from rebuilding in areas with sandy soils. Use your understanding of soil type and liquefaction to justify this decision.</p>	<p>Imagine that you found no difference between the soil type and the movement of the building. Evaluate these results and suggest what you may need to do to answer the question 'How does soil type affect building movement due to liquefaction?'</p>	<p>Science how-to p. 249</p>



6.0 The rock cycle

Have you ever imagined what the area that you live in was like millions of years ago? Geologists are scientists who study the rocks that make up Earth's surface. By making careful observations of these, and by gathering a range of other evidence, geologists have been able to work out how the rocks and the landscape around us have changed over time. Rocks can also have useful physical properties or contain useful minerals. By gathering data on their properties, geologists can then determine how best to mine them.



Learning Ladder

The Learning Ladder for each chapter maps the Science Understanding, Science as a Human Endeavour and Science Inquiry strands that will be covered. Each ladder has five levels of progression, called steps. To climb the ladders, you need to develop fluency at each step. This will help you develop the ability to complete tasks that are more complex.

5	I can evaluate the use and extraction of rocks	I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations
4	I can discuss how the properties of rocks influence their use	I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues
3	I can explain how the properties of rocks relate to their formation	I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances
2	I can differentiate between types of rock based on their properties	I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society
1	I can identify the key processes of the rock cycle	I can recognise scientific problems and solutions	I can identify socio-scientific issues
Steps in progression	Earth & space science: The rock cycle	Nature and development of science	Use and influence of science
	Science understanding	Science as a human endeavour	



Figure 6.1: The Twelve Apostles are a well-known rock formation located along Victoria’s Great Ocean Road. Each ‘apostle’ is a limestone stack that formed as the ocean eroded away the surrounding rock.

I can analyse processed data for patterns, trends, relationships and anomalies	I can communicate scientific findings and arguments for specific purposes to specific audiences	5
I can identify and discuss trends and/or patterns in a range of dataset representations	I can use digital technologies to organise and communicate data and information	4
I can process data by using mathematical relationships and/or constructing graphs	I can prepare a variety of representations to communicate ideas and findings	3
I can organise and display data using tables, keys and/or models	I can select appropriate formats to communicate ideas and findings	2
I can identify data from tables and graphs	I can identify scientific terminology used to communicate information	1
Processing, modelling and analysing	Communicating	Steps in progression
Science inquiry		

6.1 ▶ Rocks and minerals

Figure 6.2: Iron, a metal, is obtained by mining rocks that are rich in iron-containing minerals. In Western Australia, there are sedimentary rocks called banded iron formations. These rocks are billions of years old and are made of layers of iron oxide minerals alternating with layers of silica.

Learning intention

At the end of this lesson, I will be able to:

- identify that rocks contain different types of minerals
- describe minerals based on their physical properties.

Key terms

crystal: a solid substance made up of very ordered microscopic parts

element: a pure substance made of only one type of atom

mineral: a naturally occurring inorganic (non-living) substance

physical property: a characteristic or attribute of a substance that can be observed and measured, such as colour, texture, melting and boiling points, density and hardness

Investigation 6.1A

Observing minerals, p. 336

Investigation 6.1B

Extracting copper, p. 337

Key idea: Scale and measurement

Minerals are the building blocks of rocks. The types and amounts of minerals in a rock can suggest how the rock was formed and help geologists to classify it. Also, identifying rocks that contain useful mineral resources means that the minerals can be mined and used.

Minerals are made up of elements

Minerals are inorganic (non-living) substances that are found in nature. Each mineral contains one or more of the 98 naturally occurring **elements**. Most minerals are compounds, made up of two or more elements. For example, the mineral quartz is made up of silicon and oxygen (SiO_2). Some minerals are pure substances, made of only one element. These are called native elements.

Minerals have specific physical properties

Geologists identify different minerals by observing and measuring their different **physical properties**. Because each mineral has a different chemical make-up, it has a unique set of properties, including lustre, hardness, streak and crystal shape.

Lustre

‘Lustre’ refers to how light reflects off the surface of a mineral. Some minerals have a metallic lustre, which means they look shiny, like polished metal. Others have a non-metallic lustre, which means they look dull and earthy.



Figure 6.3: Some minerals, such as pyrite, have a metallic lustre.



Figure 6.4: Some minerals, such as jade, have a non-metallic lustre.

Hardness

Talc is a mineral so soft that you can scratch it with your fingernail. Diamond is also a mineral but is one of the hardest substances known. In 1812, German geologist Friedrich Mohs developed a scale to compare the hardness of minerals. His scale ranks minerals from 1 (very soft) to 10 (very hard). Hard minerals (those with larger numbers on the scale) can scratch softer minerals (those with a smaller number on the scale) (see Table 6.1).

Colour and streak

Colour is not usually a reliable way to identify a mineral because the mineral may be many different colours, or the same colour as another mineral.

Geologists use the streak of the mineral to help identify it. The streak is the powder made by scratching the mineral on an unglazed white tile. For example, gold has a gold streak colour, whereas pyrite, also known as fool's gold, has a black streak colour.

Table 6.1: The Mohs scale of hardness of minerals (from 1 softest to 10 hardest) and their relative (actual) hardness

Mineral	Mohs scale	Relative hardness (approx.)
Talc	1	1
Gypsum	2	2
Calcite	3	9
Fluorite	4	21
Apatite	5	48
Orthoclase	6	72
Quartz	7	100
Topaz	8	200
Corundum	9	400
Diamond	10	1600



▲ **Figure 6.5:** Black haematite (left) has a red-brown streak. Malachite (right) has a green streak, which is similar to its body colour.

Crystal shape

Minerals usually have a crystal structure. **Crystals** are solid substances that have a regular shape because their atoms are bonded together in a regular, repeating pattern. Different minerals have different chemical make-ups, which can be seen in the shapes of their crystals.

◀ **Figure 6.6:** Crystal shape can be used to identify minerals.

▼ **Figure 6.7:** (a) Open-cut mines access ore deposits that are close to the surface.
 (b) Underground mines are constructed to access ore bodies that are deep beneath the surface.



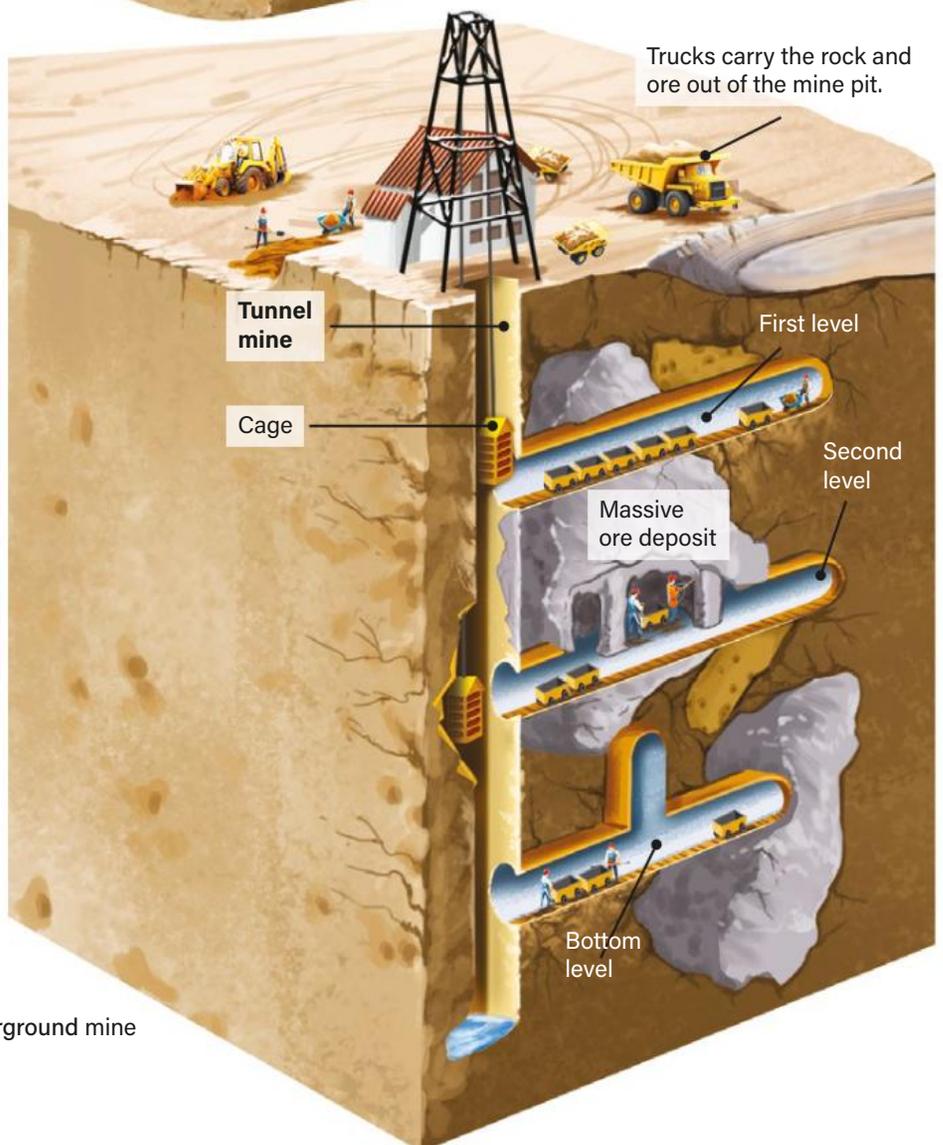
Ⓐ Open-cut mine

Mining minerals

An ore body is a mineral deposit that is profitable to mine. After an ore body has been located, mining companies need to work out the most cost-effective, safe and environmentally friendly way of removing the ore from the surrounding rock.

If the ore body is located in rock that is close to the surface, the most effective way to mine would be to remove the surface layers of rock to form an open-cut mine (see Figure 6.7a). Most of the iron ore deposits in Western Australia are mined in this way because they are close to the surface.

If the ore deposit is deep underground, it is accessed by digging shafts deep down into the rock to create an underground mine (Figure 6.7b).



Ⓑ Underground mine



Figure 6.8: The open-cut Tom Price iron ore mine in Western Australia provides access to ore bodies that are close to the surface.

Learning Ladder

The rock cycle

- 1 Complete the sentences below.
Minerals are the _____ of rocks.
They are _____ occurring substances. A native _____ is a mineral that contains only one type of _____.
- 2 Describe the main properties that are used to identify minerals.
- 3 Explain how physical properties such as lustre, hardness, colour, streak and crystal shape can be used to differentiate between different minerals.
- 4 In the mining industry, diamonds are used in saw blades to cut through rock. Use your knowledge of mineral properties to propose why this tool would be useful.
- 5 Analyse the mining methods discussed in this section and suggest which one should be used for an ore deposit located deep underground.

Use and influence of science

- 1 Identify if the following statements are true or false. If they are false, rewrite them to be true.
 - a All minerals are made of rocks.
 - b The types of minerals in a rock can help geologists to classify it.
 - c Identifying minerals that contain useful rock resources means they can be mined and used.
- 2 Propose why it is important for geologists working in the mining industry to understand how rocks that contain useful minerals are formed.

Processing, modelling and analysing

p. 240

- 1 Use Mohs' scale to identify which mineral(s) can:
 - a be scratched by apatite.
 - b be scratched by topaz but can scratch orthoclase.
 - c scratch corundum.
- 2 Construct a table to classify the minerals pictured on pages 142–43 as having metallic lustre or non-metallic lustre.
- 3 Construct two graphs using Table 6.1.
 - a Graph the mineral type against Mohs' hardness scale.
 - b Graph the mineral type against the relative hardness.
- 4 Compare your two graphs, and discuss the difference between Mohs' scale and the relative (or actual) hardness.
- 5 Analyse your graph of relative hardness. Discuss the size of the difference in relative (actual) hardness between the following pairs of minerals, and comment on how this relates to their positions in Table 6.1.
 - a Diamond and corundum
 - b Talc and quartz

Key idea: Scale and measurement

Undertake research into the age of the banded iron formations located in the Pilbara region of Western Australia. Compare the age of these rocks to the formation of Earth (4.6 billion years ago) and the extinction of the dinosaurs (66 million years ago).

Success criteria

- I can describe minerals as the building blocks of rocks.
- I can identify physical properties observed in a range of minerals.

6.2 ▶ The rock cycle

Learning intention

At the end of this lesson, I will be able to describe how sedimentary, igneous and metamorphic rocks are related through a variety of naturally occurring processes.

Key terms

deposition: a process in which sediment is left in a new place

erosion: a process in which sediments are moved from one place to another

igneous rock: rock formed from the solidification of molten rock

metamorphic rock: rock formed from another rock that has been changed by heat or pressure, or both

metamorphism: the process of change that happens to a rock because of heat or pressure, or both

sediment: small particles of rock, such as clay, sand and pebbles

sedimentary rock: rock formed by sediments that have been pressed together

weathering: a process in which rocks are worn down into smaller particles

Investigation 6.2

Modelling the rock cycle, p. 338

Key idea: Scale and measurement

Rocks are constantly changing and being recycled.

As the tectonic plates of the lithosphere move and act on each other, rocks can be pulled under Earth's surface or forced upwards.

There are three main types of rock

Geologists classify rocks into three main types based on how they were formed:

- **Igneous rocks** are made by the cooling of molten (melted) rock, either on the surface or within Earth's crust. 'Igneous' comes from the Latin word *ignis*, which means 'of fire'. The minerals in the rock can be seen as individual crystals.
- **Sedimentary rocks** are made up of **sediments** such as clay, sand, pebbles, shells and other pieces of material. The sediment is usually deposited in layers by wind, water or gravity. Over time the sediment is buried and compressed, and the particles stick together to form rock. The minerals in the rock are within the sediments and may not be easily seen.
- **Metamorphic rocks** form when other rocks change (metamorphose) because of high temperatures and pressure within Earth's crust. The minerals in the rock can be seen as individual crystals.

Rocks can change over time

The three main rock types can form from one another. Forces within Earth bring rocks to the surface or cause them to sink deep within the crust. The rock cycle is a model used to show how different processes can form the three different types of rock (see Figure 6.11). These processes may take millions, even billions, of years.

The following are some common processes that act on rocks:

- **Uplift:** Rocks are lifted up due to movements of tectonic plates.
- **Weathering:** Rocks break down into smaller pieces called sediment.
- **Erosion:** Sediment moves from one place to another.
- **Deposition:** Sediment settles in one place.
- **Burial and compaction:** As more sediment is deposited, the sediments below it are buried and squashed.
- **Cementation:** Sediments are chemically 'glued' or bonded together into rock.
- **Metamorphism:** Rocks change due to heat and pressure.
- **Melting:** Rock melts to magma due to high temperatures.
- **Solidification:** Molten rock cools and hardens.



Figure 6.9: Geologists classify rocks as igneous, sedimentary or metamorphic.

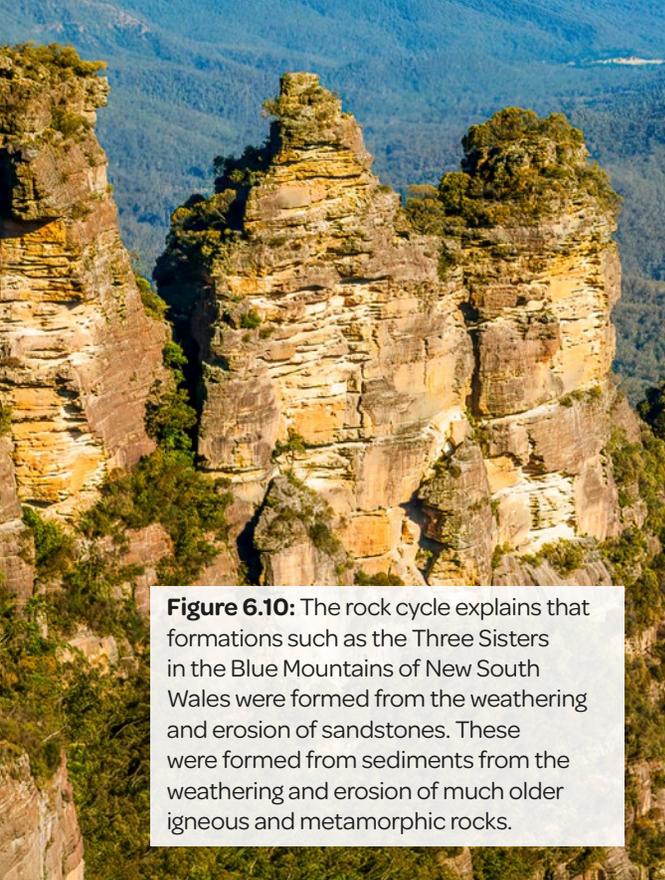
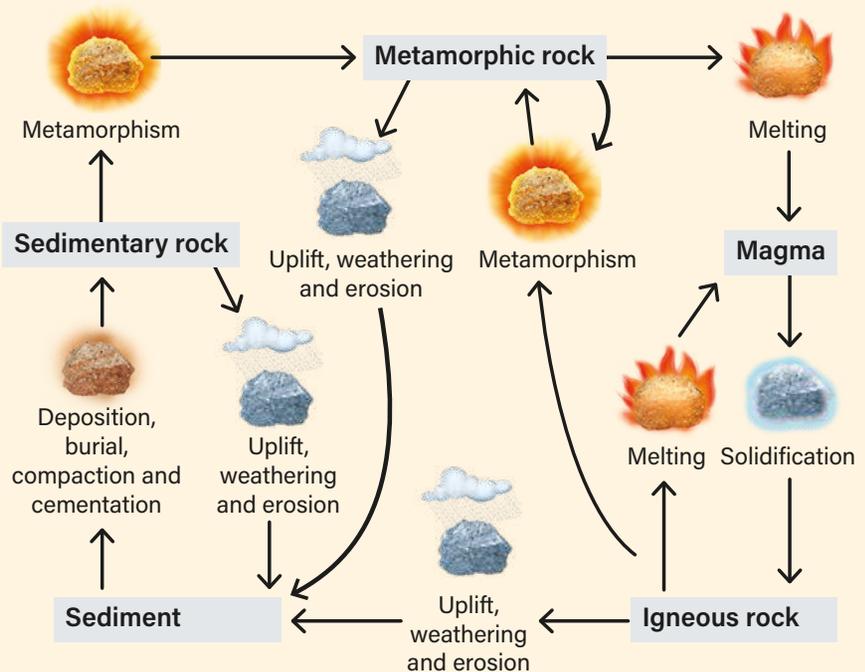


Figure 6.10: The rock cycle explains that formations such as the Three Sisters in the Blue Mountains of New South Wales were formed from the weathering and erosion of sandstones. These were formed from sediments from the weathering and erosion of much older igneous and metamorphic rocks.

▼ **Figure 6.11:** The rock cycle shows how different, naturally occurring processes in Earth form different types of rock.



Learning Ladder

The rock cycle

- Identify three natural processes that cause rocks to change.
- Identify the rock type(s) that are made:
 - of crystals.
 - of sediments.
 - by the cooling of molten rock.
 - by high temperatures and pressure.
 - Describe each of the rock types identified in part a.
- Explain how the meanings of the words 'igneous', 'sedimentary' and 'metamorphic' relate to how each type of rock is formed.

Nature and development of science

- The rock cycle is a useful model because it shows (select the best response):
 - how all rocks are different.
 - how different, naturally occurring processes form different types of rock.
 - that rocks are formed from similar processes.
- Describe how volcanologists contributed to other geologists' understanding of the rock cycle.
 - Describe how sedimentologists observing wind and waves moving sand at a beach contributed to other geologists' understanding of the rock cycle.

Communicating

p. 255

- Describe the rock cycle in your own words.
 - Rewrite your description using scientific terminology.
- Write a short story from the point of view of a piece of rock that travels through the rock cycle to end up as a quartz crystal in the Three Sisters.
- Imagine you are presenting the story you have written for Question 2 to Year 4 students. Describe some engaging ways that you could present it to them.
- James Hutton was an 18th-century naturalist known as the founder of modern geology. Conduct some research and create a digital presentation on his contributions to our understanding of the rock cycle.
- Write a short article for a geology magazine outlining reasons for and the importance of investing in research into the rock cycle.

Key idea: Scale and measurement

Rock formation can take millions of years, but some igneous rocks can form relatively quickly. Propose where and how you might observe these differences in rock formation.

Success criteria

- I can identify the three types of rock.
- I can explain what the rock cycle is.
- I can describe the main processes in the rock cycle.

6.3 ▶ Igneous rocks

Learning intention

At the end of this lesson, I will be able to:

- describe the formation and physical properties of igneous rocks
- explain how these physical properties impact how they are used and mined.

Key terms

extrusive igneous rock: igneous rock formed at Earth's surface

intrusive igneous rock: igneous rock formed under Earth's surface

solidify: become a solid

Investigation 6.3A

Cooling rate and crystal size, p. 340

Investigation 6.3B

Observing igneous rocks, p. 341

Key idea: Scale and measurement

Figure 6.12: The interlocking crystal structure can be seen in this sample of igneous rock, viewed under a microscope.

Igneous rocks form when molten rock cools and becomes hard or solid. Most igneous rocks contain interlocking crystals (connected like a jigsaw) of the minerals that were in the molten rock. The size of the crystals in igneous rocks depends on how long the molten rock took to cool. Small crystals form in rocks that have cooled quickly. Large crystals form in rocks that have cooled slowly.

Rocks can melt to form magma

What happens to chocolate when it is heated? It melts! The same thing happens to rocks. As rocks are pulled deep below Earth's surface towards the base of the lithosphere, the temperature increases. Rocks melt at temperatures of between 700 °C and 1300 °C, producing magma.

Magma is a liquid, so it is less dense than the surrounding rock and will rise to Earth's surface through faults, cracks and other weak spots, also melting the rock that it passes through. If it reaches the surface and erupts through a volcano, it is called lava.

Molten rock cools to form igneous rock

What happens to melted chocolate when it cools down? It **solidifies!** When molten rock cools and solidifies, the minerals form crystals that interlock like a jigsaw to form igneous rocks.

Rocks that form when lava cools on or near Earth's surface are **extrusive igneous rocks**. The magma has been extruded from (pushed out of) the crust. When magma reaches Earth's surface as lava, it cools very quickly, and even faster if it is under water. Extrusive igneous rocks have very small crystals, so small that they are often not visible with the naked eye. This is because they did not have very long to form before the lava solidified.

When magma cools under the surface, it forms **intrusive igneous rocks**. The magma has intruded on the rocks that were originally there. Magma under the surface cools very slowly, which means the crystals have more time to grow. The crystals in intrusive igneous rocks, such as granite, are much larger than those in extrusive igneous rocks and can be seen with the naked eye.

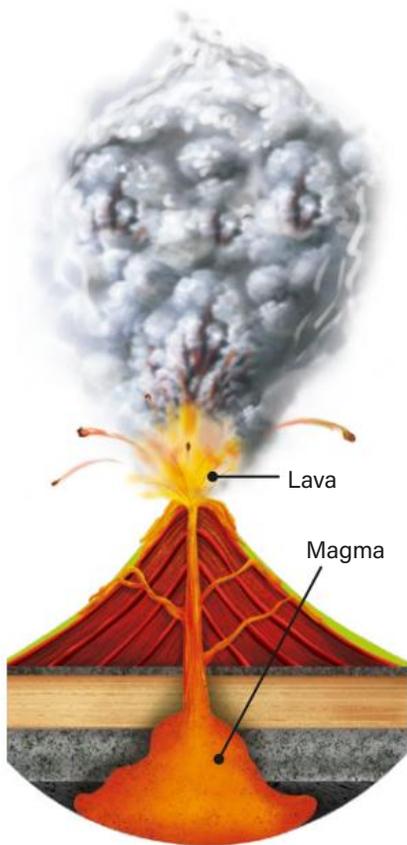


Figure 6.13: Magma collects in a chamber of a volcano before making its way to the surface to erupt as lava.

Use and mining of igneous rocks

Igneous rocks are useful for many purposes. Their crystal structure means they are hard and strong, and so rocks such as granite are quarried for use in construction and even for decorative purposes such as kitchen benchtops. Igneous rocks can also include valuable metals such as copper and gold, plus gemstones like rubies and emeralds, and so they are mined so that these can be extracted.

Mining processes depend on the location of the igneous rock. Rocks used in construction are usually extracted in open-cut quarries. However, underground mining techniques may need to be used to extract gemstones if the deposit is under the surface.



Figure 6.14: Sawn Rocks in Mt Kaputar National Park near Coonabarabran in New South Wales are made of columns of basalt, an extrusive igneous rock. As the lava flow cooled, it shrank, creating long hexagonal 'pipes'.

Learning Ladder

The rock cycle

- 1 Complete the sentences below.
 - a Molten rock below Earth's surface is known as _____. Molten rock at the surface is known as _____.
 - b Extrusive igneous rocks form when molten rock _____ and _____.
- 2 Describe two key characteristics that could be used to classify a rock as igneous.
- 3 Explain how the time taken to cool affects the observable characteristics of an igneous rock.
- 4 Granite is an igneous rock that is commonly used in kitchen benchtops. Use your knowledge of igneous rocks to discuss why granite is an appropriate material for this purpose.
- 5 Evaluate how igneous rocks are used, in relation to their physical properties.

Use and influence of science

Copper is a metal that is relatively abundant and a good conductor of electricity. Many copper deposits are found in igneous rocks, as they formed when magma was rising to the surface.

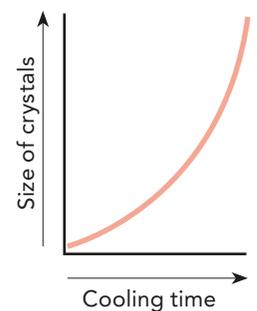
- 1 Conduct research to identify some common problems associated with the mining of copper from igneous rocks.
- 2 Suggest why it is important for geologists to understand what type of rocks copper deposits are found in.

- 3 A copper deposit is found close to the surface and an open-cut mine is proposed. Conduct research to identify how the construction of this mine could damage the environment.

Processing, modelling and analysing

p. 240

- 1 Identify what happens to the size of the crystals as the cooling time increases.
- 2 Copy the graph from Question 1 in your notebook. Plot and label points along the trendline to represent each of the rocks listed below.
 - a Granite – large crystals
 - b Rhyolite – medium/small crystals
 - c Pumice – small/no crystals



Key idea: Scale and measurement

Some rocks can form over a long timescale, while others form quite quickly. Write a short story or create a comic strip that compares the formation of a crystal in an intrusive igneous rock such as pumice with the formation of a crystal in an extrusive igneous rock such as granite.

Success criteria

- I can describe the features and properties of igneous rock.
- I can explain how igneous rocks are formed.
- I can explain how properties of igneous rocks relate to their use.

6.4 ▶ Metamorphic rocks

Learning intention

At the end of this lesson, I will be able to:

- describe the formation and physical properties of metamorphic rocks
- explain how these physical properties impact how they are used and mined.

Key terms

contact metamorphism: the process of change that happens to rock over small areas, often near volcanoes

regional metamorphism: the process of change that happens to rock over large areas

Investigation 6.4A

Modelling contact metamorphism, p. 342

Investigation 6.4B

Observing metamorphic rocks, p. 343

Key idea: Scale and measurement

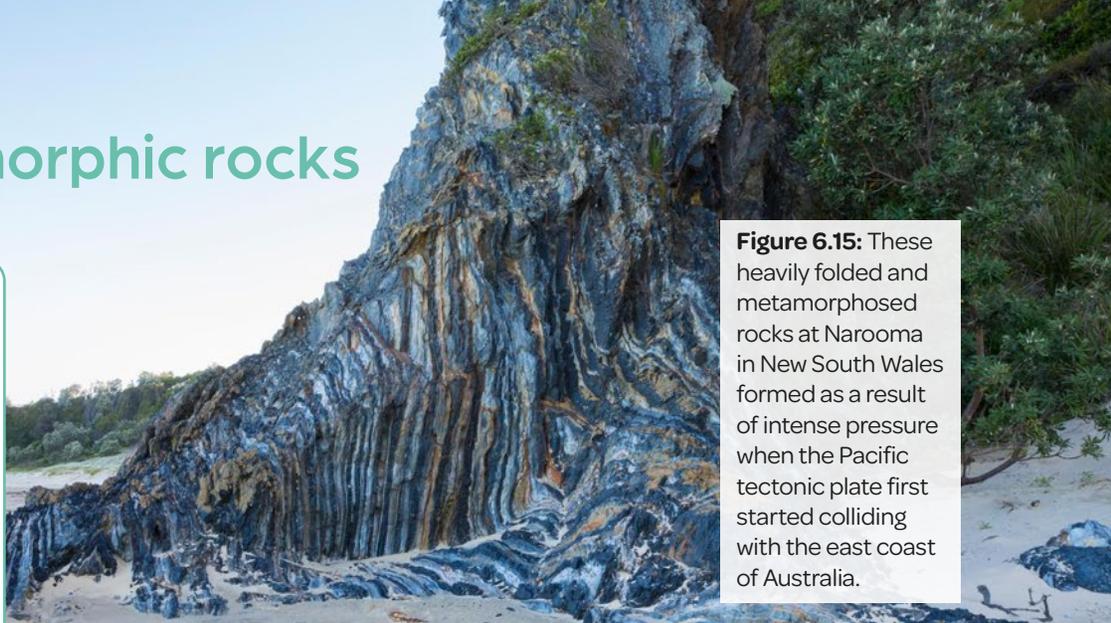


Figure 6.15: These heavily folded and metamorphosed rocks at Narooma in New South Wales formed as a result of intense pressure when the Pacific tectonic plate first started colliding with the east coast of Australia.

Metamorphosis means 'change'. A metamorphic rock has changed its form. Metamorphic rocks form from other rocks that have been changed by heat or pressure, or both.

Rocks are changed by heat and pressure

The process by which rocks are changed by extreme heat, pressure or both is called metamorphism. It happens when Earth's tectonic plates push together, move apart or slide past each other. In the process, rocks are buried and become very hot under pressure. This causes the minerals inside them to rearrange. Some may form new minerals by chemically reacting with each other or with fluids passing through the rocks. Metamorphism results in rocks that have crystals, sometimes arranged into layers.

Geologists compare the types of minerals in metamorphic rocks to work out where and how the rocks formed. This can help them to understand more about how Earth's tectonic plates move and act on each other.

Rocks can be squashed and folded, or 'cooked'

Rocks can be metamorphosed by two major processes.

Regional metamorphism happens over large areas and over thousands to millions of years, when two tectonic plates push together. This puts rocks under much higher temperatures and pressures, and they may squash and fold. As they are pushed deeper and deeper, they keep changing as the temperature and pressure increase. Rocks that have been formed by regional metamorphism have crystals arranged in layers.

Figure 6.16: Regional metamorphism happens when two tectonic plates push together. As the plates collide, the increase in pressure and temperature will cause the rocks to change over a very large area.

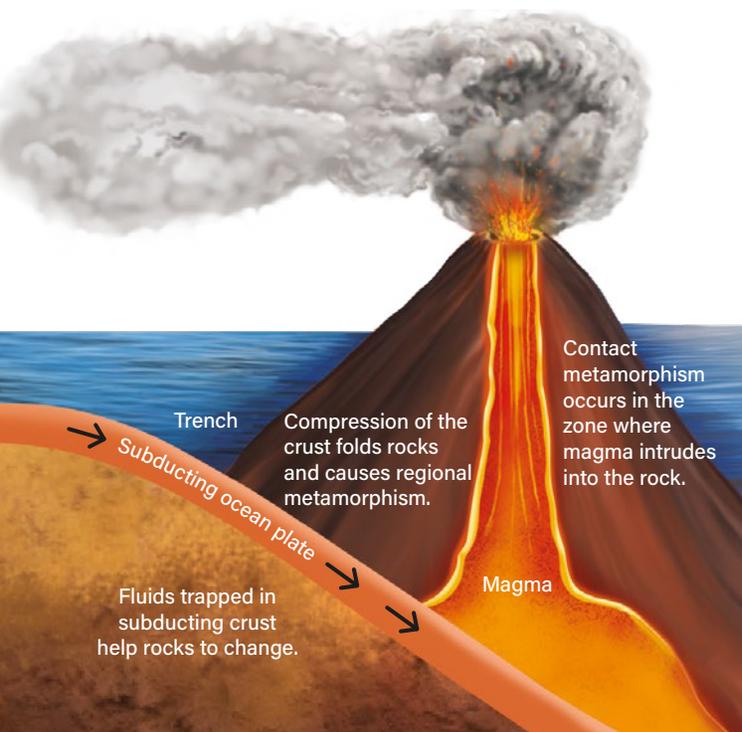


Figure 6.17: ▶ Garnets are gemstones formed when sedimentary rocks such as shale are subjected to heat and pressure at a convergent plate boundary (regional metamorphism).



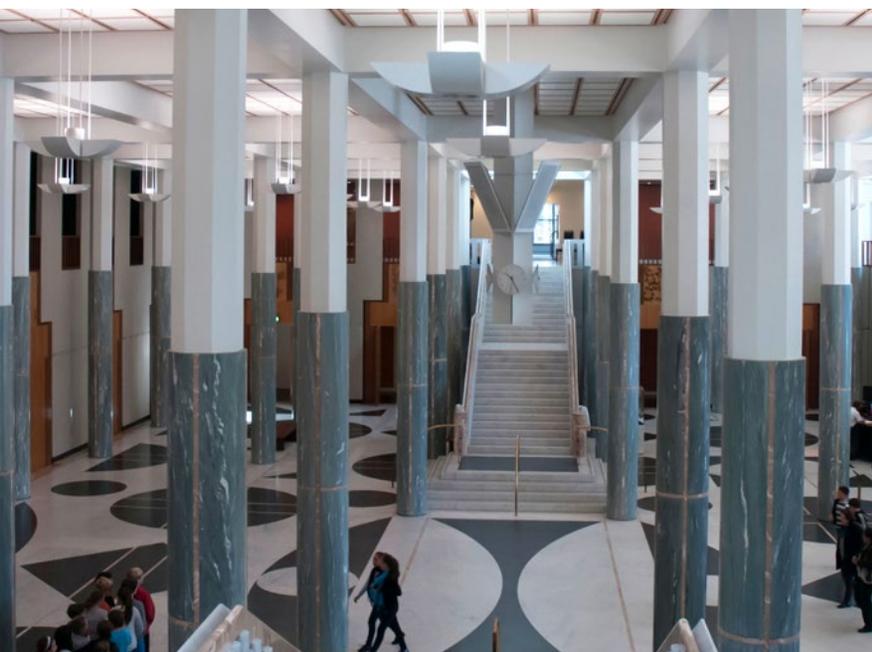
Contact metamorphism happens when a body of rising magma meets rock, increasing the temperature of the rock and ‘cooking’ it, forming new crystals. It happens in a small local area, often around volcanoes, and happens relatively quickly. The crystals in rocks formed by contact metamorphism are not in layers.

Use and mining of metamorphic rocks

Metamorphic rocks are hard and strong. Slate, which is hard but easily split into thin layers, is often used in construction. Marble is used for more decorative purposes, such as floors, benches and sculptures. The process of metamorphism can also help to concentrate useful minerals such as those that contain iron, nickel and platinum, or encourage the growth of gemstones.

Mining processes depend on the location of the metamorphic rock. Most rocks used for construction and decoration are extracted from open-cut quarries. However, underground mining techniques may need to be used to extract minerals and gemstones if the deposit is under the surface.

▼ **Figure 6.18:** The foyer of Parliament House in Canberra is decorated with hard-wearing marble.



Learning Ladder

The rock cycle

- 1 Complete the sentence below.
Metamorphic rocks are formed when _____ have been _____ due to _____, _____ or both.
- 2 Describe two key characteristics that could be used to classify a rock as metamorphic.
- 3 Explain how heat and pressure cause changes in metamorphic rocks.
- 4 Marble is a hard and durable metamorphic rock. Discuss why it is often used in sculptures.
- 5 Evaluate how metamorphic rocks are used, in relation to their physical properties.

Use and influence of science

Slate is a metamorphic rock that is formed from a fine-grained sedimentary rock called shale. As a result, it can be easily split into thin, but strong, layers.

- 1 Propose one argument that can be used to support the use of a natural resource like slate in construction.
- 2 Describe how scientific knowledge about the properties of slate can inform how it is used.
- 3 Conduct research to find out how slate is quarried. Explain some of the environmental impacts of the process.

Communicating

p. 255

- 1 Create a glossary of terms, including those not already in the list of key terms, relating to metamorphic rocks.
- 2 Brainstorm ways to communicate to Year 6 students how metamorphic rocks form.
- 3 Select your preferred option from Question 2 to construct.

Key idea: Scale and measurement

Discuss how understanding the timescales required for metamorphic processes can help us to better understand the rock cycle.

Success criteria

- I can describe the features and properties of metamorphic rock.
- I can explain how metamorphic rocks are formed.
- I can explain how properties of metamorphic rocks relate to their use and how they are mined.

6.5 ▶ Sedimentary rocks

Figure 6.19: Limestone often contains fossils.

Learning intention

At the end of this lesson, I will be able to:

- describe the formation and physical properties of sedimentary rocks
- explain how these physical properties impact how they are used and mined.

Key terms

chemical sedimentary rock:

sedimentary rock formed from layers of mineral crystals that have crystallised from water

clastic sedimentary rock:

sedimentary rock made of sediments cemented together

organic sedimentary rock:

sedimentary rock formed from the remains of plants or animals

Investigation 6.5A

Modelling the formation of sandstone, p. 344

Investigation 6.5B

Observing sedimentary rocks, p. 345

Key idea: Scale and measurement

Igneous and metamorphic rocks are formed by changes in Earth's crust. Rocks on Earth's surface also change. Wind, water, vegetation and changes in temperature can act on these rocks, wearing them down into smaller parts called sediments and depositing them in new locations. When these sediments are buried, compacted and cemented together over time, they form sedimentary rock.

Rocks are worn away by weathering

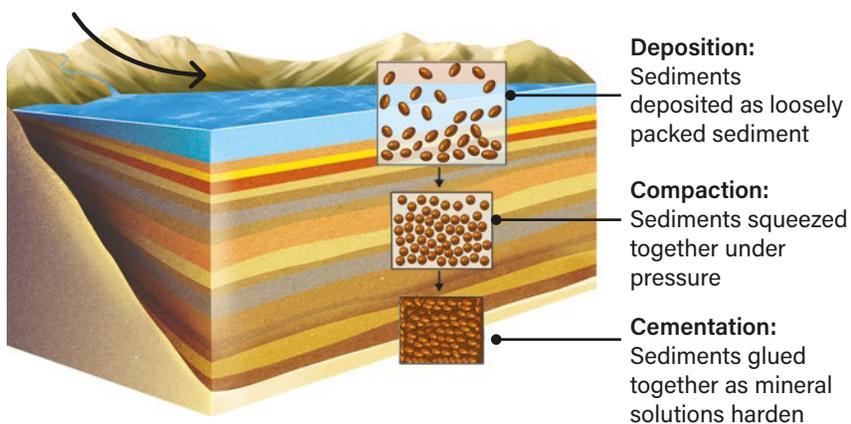
Weathering is the process by which rocks are worn away into sediments such as pebbles, sand and clay. There are two main ways this can happen.

Physical weathering breaks rocks into smaller particles through processes that do not change the chemical make-up of the minerals. This can happen when rocks expand, shrink and crack due to temperature changes, or if they are worn down by wind or water.

Chemical weathering breaks rocks into smaller particles through chemical reactions that change the minerals in the rocks. This can happen when rocks have contact with chemicals in the air or water. The new minerals may separate from the original rock to form sediments, or they may even dissolve in the water and be transported away. The weathering process generally happens very slowly. For example, it can take millions of years for rocks to be worn away by the wind or for caves to form.

Figure 6.20: Sedimentary rocks are formed when sediments are eroded, deposited, compacted and cemented together.

Erosion: Sediments carried away from their source by water or wind



Erosion moves sediment

Erosion is the movement of sediment from one place to another. The sediments can be transported by wind, water, ice or gravity; these are called the agents of erosion.

Deposition drops sediment in new areas

Deposition happens when erosion deposits (drops) sediments in a new place. Often this happens when there is no longer enough energy in the wind or water to carry them any further. Deposition can happen slowly over very long periods of time; it can take thousands

or millions of years, depending on the amount of erosion. Sometimes deposition can happen very quickly due to events such as landslides and floods.

Compaction and cementation forms rocks

If the sediments are not eroded after they are deposited, they may eventually be compacted and cemented together to form **clastic sedimentary rock**. As the layers of sediments build up, pressure on the sediments increases and they are compacted together. Chemicals in the groundwater that moves between the sediments will then cement the layers together, forming a hard rock.

Organic sedimentary rocks are formed from the remains of plants and animals. These remains have been deposited, buried, compacted and cemented together. Limestone is made of the remains of ancient coral reefs and often contains fossils. Coal is formed from the remains of plants that died and became buried in ancient swamps. The remains did not decompose. Instead, when they were buried, the increasing pressure compacted and cemented the remains and changed them into coal – this is why it is called a fossil fuel.

Chemical sedimentary rocks are formed when water that contains dissolved minerals evaporates, allowing the mineral crystals to grow, often in layers. Halite (rock salt) is formed in this way.

Use and mining of sedimentary rocks

Sedimentary rocks are useful for many purposes. Sandstone is often used in construction because it is strong but easy to shape. Limestone can be used to make lime, a material that is used in many different industrial processes. Sedimentary rocks can often be sources of important minerals that are deposited as part of sedimentary processes, such as gold, iron and halite. Furthermore, sedimentary rocks can also contain fossil fuels such as coal, oil and natural gas.

Mining processes depend on the location of the sedimentary rock. Most rocks used for construction are extracted from open-cut quarries. However, underground mining techniques may need to be used if the deposit is under the surface.

Learning Ladder

The rock cycle

- 1 Complete the sentences below.
 - a Rocks are worn away by _____.
 - b _____ moves sediment.
 - c _____ drops sediments in new areas.
 - d The processes of _____ and _____ turn sediment into rock.
- 2 Describe two key characteristics that could be used to classify a rock as a sedimentary rock.
- 3 Explain how a clastic sedimentary rock forms.

Use and influence of science

In Victoria's Latrobe Valley, coal seams are close to the surface and between 100 and 200 metres thick. To mine this coal, the surface layers are removed to access the coal seams. The coal is then transported to the nearby power plant, where it is burnt to create electricity.

- 1 Identify which of the following statements is correct.
 - A Coal is made from the remains of ancient coral reefs and mining it damages forest habitats.
 - B Fossil fuels, such as coal, are burnt to create energy, but can also cause environmental damage.
- 2 Propose why coal-fired power plants were built in the Latrobe Valley.
- 3 Victoria's Hazelwood coal mine and power station were shut down in 2017. Conduct research to outline some of their environmental impacts.
- 4 Discuss the impact of the rehabilitation at the site.
- 5 Analyse how improvements from mine rehabilitation may shape people's view of mining.

Processing, modelling and analysing p. 240

- 1 Use Figure 6.20 to identify the steps required to form a clastic sedimentary rock.
- 2 Construct a series of diagrams to model how clastic sedimentary rock is formed.

Key idea: Scale and measurement

Conglomerate, mudstone and sandstone are types of sedimentary rock. Research what sediments they are made from, including their size, the environments they are formed in and how long they can take to form.

Success criteria

- I can describe the features and properties of sedimentary rock.
- I can explain how sedimentary rocks are formed.
- I can explain how properties of sedimentary rocks relate to their use and how they are mined.

6.6 ▶ Fossils

Figure 6.21: The fossils found in the rocks at Ediacara in South Australia are a very important part of the fossil record. They show the imprint of soft-bodied organisms in sandstone and are some of the oldest fossils of complex life in the world at more than 550 million years old.

Learning intention

At the end of this lesson, I will be able to describe how fossils form.

Key terms

fossil: preserved remains or traces of once-living things

fossil record: the history of life on Earth as documented by fossils

fossilisation: the process of the formation of a fossil

Investigation 6.6

Making 'fossils', p. 346

Key idea: Scale and measurement

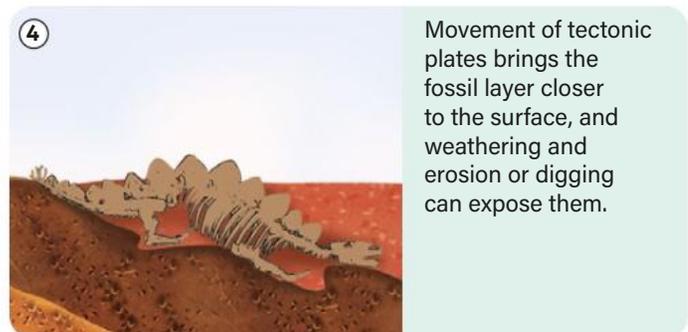
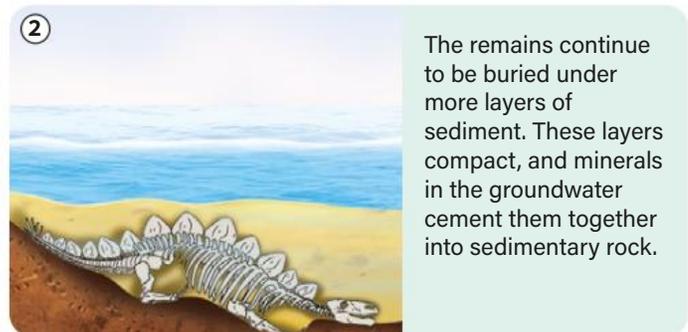
Fossils are the preserved remains or traces of once-living things. They can be complete or part skeletons, shells and tree trunks, or traces that an animal existed, such as footprints, burrows and even poo. Palaeontologists study fossils and the rocks they are found in to reconstruct information about past living things and the environments they lived in.

How fossils are formed

The process that results in a fossil is called **fossilisation**, and it is rare. Usually when an organism dies, it decomposes or is eaten. Soft parts decay or are eaten quickly, and even hard parts such as bones and shells are eventually eaten or weather away if they are left exposed.

For a fossil to form, a series of events that preserves an organism needs to happen, as shown in Figure 6.22.

▼ **Figure 6.22:** The fossilisation process





◀ **Figure 6.23:** A skeleton of a *Muttaborrasaurus langdoni*, found at Muttaborra in Queensland. This dinosaur has been chosen as Queensland's fossil emblem.

Figure 6.24: This 100-million-year-old mosquito has been preserved in amber.



While most fossils are usually found in sedimentary rocks, plant and animal remains can sometimes be found preserved in amber (fossilised tree sap), tar and permafrost (ground that is always frozen). These things often preserve the soft parts of organisms that would not usually be preserved in rock.

Footprints and burrows can also be preserved by fossilisation. These trace fossils can suggest how animals moved and lived, in a way that skeletons cannot.

Fossils of coral in limestone indicate warm, shallow seas; dinosaur footprints in mudstone suggest they may have been left along the muddy edge of a lake.

The fossil record shows what life used to be like

Fossils provide evidence that different organisms existed at different times in the geological history of the Earth (the **fossil record**). Palaeontologists use different techniques to estimate how old a fossil of an organism is and to compare it to other fossils. This can provide them with information about how groups of organisms have changed over time, along with major events on Earth that caused many species to become extinct (mass extinctions). Some of the most important fossils in the fossil record are those that are rare or that show the evolution of new features in particular life forms.

Learning Ladder

The rock cycle

- 1 Select the option below that best shows the processes in the rock cycle that are important for fossils to form.
 - A Melting, burial and compaction, erosion
 - B Deposition, burial and compaction
 - C Deposition, erosion, melting
 - D Weathering, deposition, melting
- 2 Describe, using scientific terminology, how a fossil is formed.
- 3 Propose why fossils that include feathers and other soft body parts are rare.
- 4 Explain the key properties of a rock that a fossil would be found in.
- 5 Evaluate why palaeontologists are also interested in the physical properties of the rock that a fossil is found in.

Nature and development of science

- 1 Imagine you are investigating the best environments for fossil formation. Identify the environment(s) below that a fossil would most likely form in.
 - A Sandy desert
 - B Mountain range
 - C Lake
- 2 Describe how palaeontologists and biologists could work together to develop our understanding of the history of life.

Communicating

p. 255

- 1 Create a glossary of scientific terms, including those not already in the list of key terms, used to explain the process of fossilisation.
- 2 Summarise the different types of fossils referred to on these pages in a table that clearly communicates the information.
- 3 Imagine you are the stegosaurus in Figure 6.22. Write a social media update for each of the four steps, describing what is happening to you.

Key idea: Scale and measurement

Conduct some research into the fossil record and the geological timescale. Create your own representation of major events such as the evolution of unicellular life, multicellular life, land plants, fish, amphibians, reptiles, birds, mammals and dinosaurs.

Success criteria

- I can describe how fossils form.
- I can explain how fossils can be used to provide evidence of past life and environments.

6.7 ▶ First Nations Peoples' use of resources

Learning intention

At the end of this lesson, I will be able to explain how First Nations Peoples have used different types of resources such as minerals for various purposes for tens of thousands of years.

Key terms

andesitic hornfels: a dark, fine-grained metamorphic rock known for its distinct green colouring and hardness

binding agent: a substance that holds other materials together to form a cohesive whole

crystalline: having the structure and form of a crystal

thermoplastic: a substance that becomes plastic when heated and hardens when cooled, and can undergo these processes repeatedly

Key idea: Scale and measurement

Human societies have always needed to access and use the resources in the environment to live well. As well as the basic necessities of clean water, nourishing food and robust shelter, humans have used other resources to make challenging tasks easier. These have included a variety of materials, including organic items such as animal skins, wood, bone and various grasses, and inorganic items such as various minerals and rocks. The choice of what resource to use has always been shaped by both the characteristics of the material (e.g. its hardness and how easy it is to work with) and its availability in the environment. In cases where these resources were not readily available, people would usually trade with others to access them.



Minerals have been used as tools and in tool making

Some of the most common and useful tools that Aboriginal and Torres Strait Islander Peoples have used are grinding stones, stone axes and knives. Minerals are selected according to the element or elements in the mineral, and its hardness, which is often determined by the **crystalline** structure.

Greenstone (**andesitic hornfels**) from Mt William in central Victoria has been dated to the Cambrian period, 541–485.5 million years ago. Movement of tectonic plates produced heat and pressure, which acted on the minerals to create the distinctive crystalline structure of greenstone.

Greenstone is useful because of its hardness. It would be chipped from the quarry with a hammer stone and then shaped into an axe head with a grinding stone. An axe head would often be ground with a groove towards the rear to help secure it to a wooden haft with twine and **thermoplastic** resin.

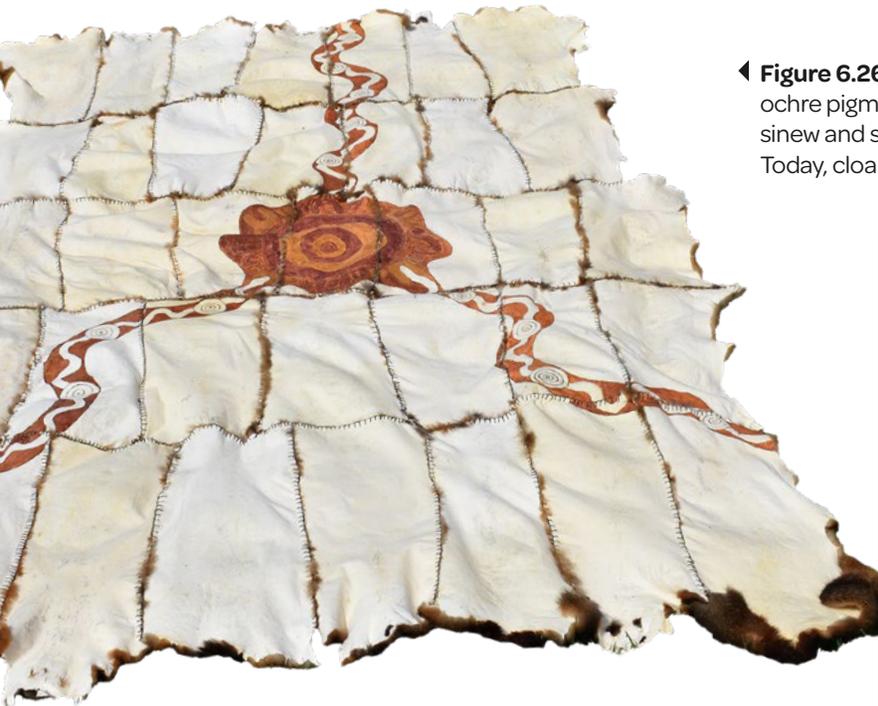


◀ **Figure 6.25:** This is a stone axe head made from basalt, a very hard rock found across Australia. At one point, the head would have been secured to a wooden haft with twine and thermoplastic resin.

The axes have been used for over 50 000 years to cut into wood to access possums, insects, larvae or eggs, as well as to cut through bark to create canoes or building materials. The hard axe heads could be used for a long time before they needed resharping. Greenstone axe heads were highly valued and have been found many thousands of kilometres away from the quarry site.

Minerals were used to make pigments

Softer minerals such as ochre have been used to make pigments. The colours of ochre range from a deep chocolate brown through to lighter browns, reds, oranges, yellows and whites and relate to the different pigments in the mineral. The reds and browns often have higher concentrations of iron oxides, and the yellows and whites often have kaolinite and lower levels of metal oxides.



◀ **Figure 6.26:** This possum skin has been decorated with paints made from ochre pigment, water and black wattle sap. Originally, possum or kangaroo sinew and sharpened possum bones were used to sew the pelts together. Today, cloaks are sewn using waxed nylon thread and metal gloving needles.

Ochres are usually very soft and water soluble, which makes them useful as pigments and paints. Ochres have been used in art on rock walls, bark and wooden objects and animal skins, and are also commonly used as body paint for ceremonial purposes. Often, there are restrictions as to who is allowed to work with or wear certain colours of ochre, and which ceremonies they can be worn at. This can relate to sex and gender, age, initiation and adulthood, or Elders and elderhood, as well as births, deaths, marriages, conflicts and celebrations.

Ochres are often mixed with a **binding agent** such as the sap from black wattle (*Acacia mearnsii*) and water. This gives the ochre a paint-like consistency and allows it to stick to the animal skin. The ochre commonly needs to be reapplied periodically because it flakes away and rubs off with use.

Figure 6.27: A First Nations person is grinding a stone containing red ochre. The powder this produces will be mixed with water to make paint and used for ceremonial purposes. Ochre quarries are commonly highly valued as sacred places.



Learning Ladder

The rock cycle

- 1 Identify key processes that formed greenstone.
- 2 Compare the properties of greenstone and ochre.
- 3 Explain how the properties of greenstone relate to how it is sourced and used.
- 4 Discuss how the properties of ochre influence how it is used.

Nature and development of science

- 1 Propose a problem that a greenstone axe might have addressed.
- 2 Consider the possum cloak in Figure 6.26. Describe why it is important that many different sciences have worked together to make it.
- 3 Discuss how new understandings of ochre can impact who is allowed to work with or wear certain colours.
- 4 Discuss how the threads used to create possum skin cloaks have changed over time. Propose two reasons why.
- 5 Using examples, analyse how First Nations Peoples' knowledge of resources and their use may help in developing new scientific inventions.

Communicating

p. 255

- 1 Recall the scientific name of greenstone.
- 2 Consider the stone axe head in Figure 6.25. Construct a diagram with each part of the axe labelled.
- 3 Construct a poster detailing the different uses of ochre and greenstone.

Key idea: Scale and measurement

Create a timeline and use an appropriate scale. At one end of the timeline, mark when the greenstone was formed, mark when it was used to create various stone tools, and mark when the Australian continent was colonised. Analyse what this indicates about the science of greenstone.

Success criteria

- I can explain how First Nations Peoples have used scientific reasoning to ensure that materials with favourable characteristics have been used to create appropriate tools.
- I can describe how, for tens of thousands of years, First Nations Peoples have often used multiple materials at the same time to create tools and art, and as part of ceremony.

6.8 ▶ Key idea: Scale and measurement – history in the rocks

Learning intention

At the end of this lesson, I will be able to:

- explain how geological history can be interpreted from a sequence of sedimentary layers
- describe how the geological timescale describes the history of Earth.

Key terms

geological history: how Earth has changed over time

law of superposition: older rocks are found beneath younger rocks in a sequence

relative age: the approximate age of a rock determined by comparing it to another rock

sequence: the order of something

Key idea: Scale and measurement

Geologists can piece together the **geological history** of different locations by investigating the **sequence** of rocks in the area. The rocks that were deposited hundreds of millions of years ago contain important clues to what life and environments were like early in the history of Earth.

The youngest rocks are at the top

When sedimentary layers are deposited, younger ones are deposited on top of older ones. Unless something unusual has happened, the oldest rocks in a cliff face are at the bottom and the youngest rocks are at the top. This is known as the **law of superposition** and geologists use it to work out the **relative age** of the layers. Finding the same layers in different areas means the layers must have been deposited at the same time.

Rocks tell the story of geological history

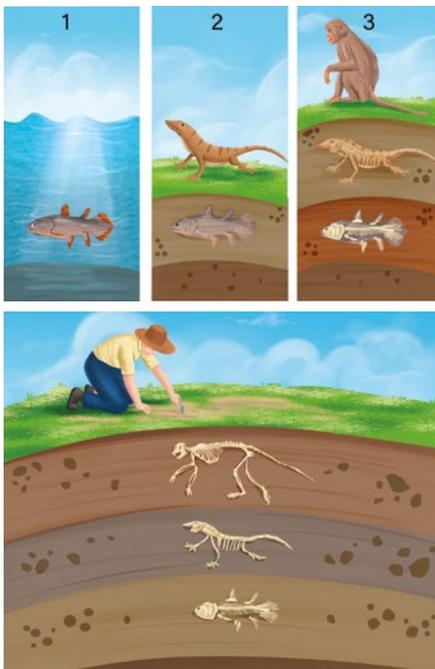
If you are looking at a cliff face and observe different types of sedimentary rock, you can work out its geological history. This is because different rocks are deposited in different environments. Fossils in the rocks also provide information and can be used to work out how old the rocks are. The presence of igneous rocks might mean that a volcanic eruption happened.

The origins of Uluru date back more than 500 million years

Uluru is made of layers of very hard sandstone. By studying these layers, geologists have been able to determine how the rock was formed. The sandstone was formed when a nearby ancient mountain range, similar to the modern Himalayas, was weathered, eroded and deposited in a valley more than 500 million years ago. Over time, this sediment was buried, compacted and cemented together, forming very hard rock. As tectonic plates pushed together, this rock was folded and pushed up to the surface again. The softer rock weathered and was eroded, leaving only the hard rock of Uluru at the surface. It is just the tip of a large section of rock that may reach as far as five kilometres below the surface.

▼ **Figure 6.29:** Uluru is made of layers of very hard sandstone.

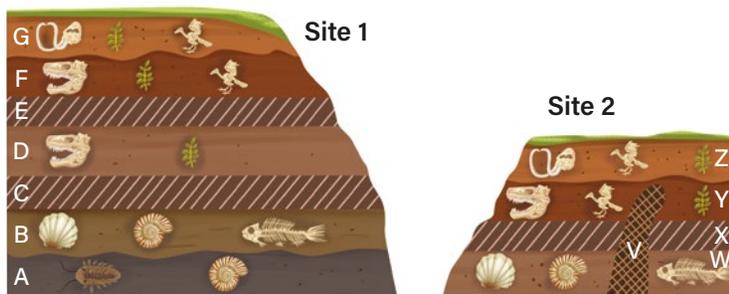
Rock layers are deposited from the bottom up ...



... so the deeper we dig, the further back in time we see.

▲ **Figure 6.28:** Geologists can work out the geological history of an area by comparing the layers of sediment.





Key		
	Trilobite	
	Bird	
	Ammonite	
	Fish	
	Extrusion (lava)	
		Intrusion

Figure 6.30: The law of superposition along with knowledge of how different types of rocks form can help us to interpret the geological history of an area. We can also use this information to link two different sites together if they contain the same rocks and fossils.

Geological timescale

The geological timescale divides the 4.6 billion years of Earth's history into units of time based on the rock record. Divisions are based on fossils and other properties of the rocks that can be found around the world that have been deposited at the same time. Key events or a change in the characteristics of the rocks, such as mass extinctions, mark the end of one unit of time and the start of the next.

Aeon	Era	Period		
Phanerozoic	Caenozoic	Quarternary	Humans	
		Neogene		
		Paleogene		
	Mesozoic	Cretaceous		
		Jurassic	Birds	
		Triassic	Mammals	
	Palaeozoic	Permian		
		Carboniferous	Reptiles	
		Devonian	Amphibians	
		Silurian		
		Ordovician	Fish	
			Cambrian	Shelled invertebrates
	Precambrian	Proterozoic	Ediacaran	
			Cryogenian	Origin of Earth
Tonian				

Figure 6.31: The geological timescale

Learning Ladder

The rock cycle

- Complete the sentence below.
Generally, the youngest layers of rocks are found on the _____ [top/bottom] and the oldest rock layers are found on the _____ [top/bottom].
- Describe the changes that occurred in Uluru over its long period of formation.
- Explain why layers of different types of rock in a cliff face can tell you about its geological history.
- Identify the oldest and youngest rock layers in Figure 6.30.
 - Discuss whether this can be determined from observing just the one location. Support your response with evidence from the figure.
 - Propose a reason why there are differences in the rock layers at the two locations.

Nature and development of science

- Identify the solution that best outlines how to work out which rocks are oldest.
 - The geological timescale tells us the age of a rock.
 - The law of superposition identifies the oldest rock.
 - The oldest rock is always at the bottom of a rock cutting.
- Describe the importance of gathering data from all around the world in the development of the geological timescale.

Communicating

p. 255

Conduct some research into an Australian rock formation other than Uluru to find out how it was formed.

- Construct a glossary of scientific terms that you came across in your research.
- Compile some research notes that summarise the key points from your research.
- Use your research notes to construct simple diagrams illustrating the steps it took for the rock formation to form.
- Use digital technologies to present information on how the rock formation formed in a way that you can share with your peers.
- Design a sign for tourists to be placed at the rock formation that summarises your findings about it.

Success criteria

- I can identify in a sequence of sedimentary rocks where the youngest and oldest rocks can be found.
- I can describe how the geological timescale can be used to describe the history of Earth.

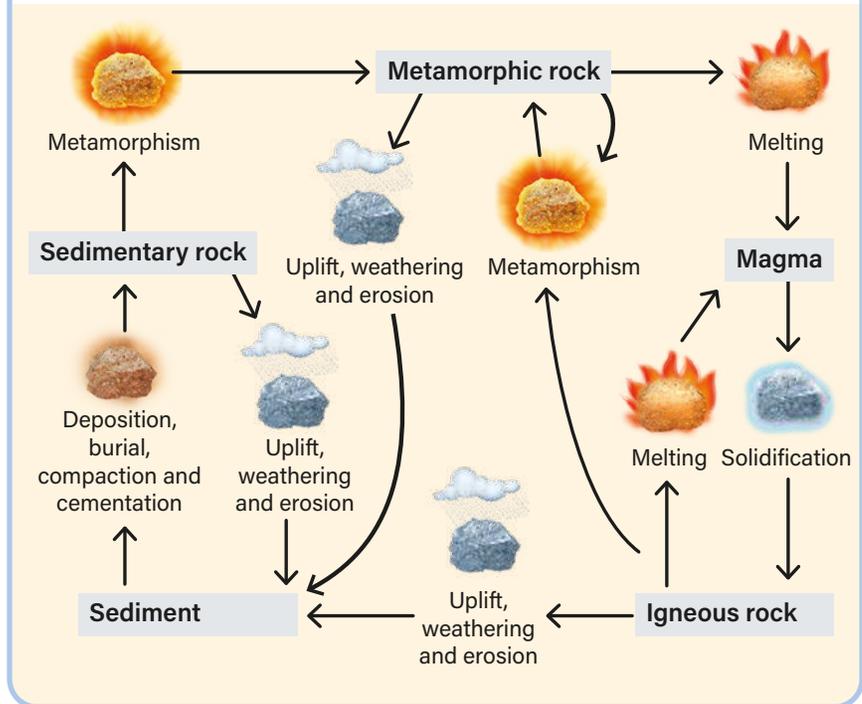
► Summary

- Minerals are the building blocks of rocks.
- They are inorganic substances found in nature and are usually compounds made of two or more elements.
- Geologists identify minerals by observing and measuring properties such as lustre, hardness, colour, streak and crystal shape.



The rock cycle shows how different, naturally occurring processes form different types of rock. The three main types of rock are:

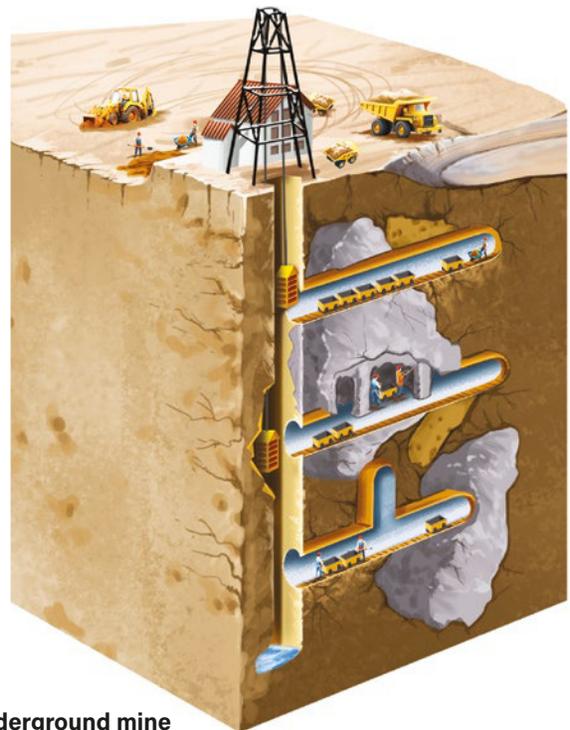
- **igneous:** made by the cooling of molten rock
- **metamorphic:** made from older rocks that have been changed
- **sedimentary:** made of sediments weathered and eroded from older rocks.



- An ore body is a deposit of minerals that is profitable to mine.
- If the ore body is located close to the surface, it can be mined using an open-cut method.
- If the ore body is located deeper underground, it can be mined by digging shafts deep underground.



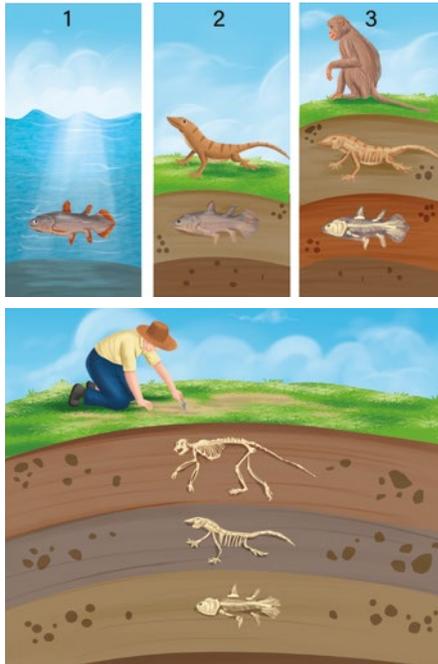
Open-cut mine



Underground mine

- Fossils are the preserved remains or traces of once-living things.
- Fossils, and the rocks they are in, can help palaeontologists, who study fossils, to reconstruct information about past living things and the environments they lived in.

Rock layers are deposited from the bottom up ...



... so the deeper we dig, the further back in time we see.

- First Nations Peoples selected mineral resources for specific purposes, depending on their characteristics. Very hard rocks and minerals would be used to make tools such as grinding stones, axes and knives.
- Softer minerals, such as ochre, are used to make pigments and paints. The colour of the ochre is determined by the concentration of different pigments in the mineral.



Key idea: Scale and measurement

The geological timescale divides the 4.6 billion years of Earth's history into units of time based on the rock record.

Aeon	Era	Period	
Phanerozoic	Cenozoic	Quarternary	Humans 
		Neogene	
		Paleogene	
	Mesozoic	Cretaceous	
		Jurassic	Birds 
		Triassic	Mammals 
	Palaeozoic	Permian	
		Carboniferous	Reptiles 
		Devonian	Amphibians 
		Silurian	
		Ordovician	Fish 
		Cambrian	Shelled invertebrates 
	Precambrian	Proterozoic	Neo-proterozoic
Ediacaran			
Cryogenian			Origin of Earth
		Tonian	

Demonstrate your understanding

3

4

5

Use your knowledge of the rock cycle to explain how the Ediacaran sandstone formed.	Discuss how the environment the Ediacaran Fauna lived in allowed them to be preserved.	There are many different layers that contain the Ediacaran Fauna. Analyse how this would impact extracting the fossils.	
Explain how the discovery of Ediacaran Fauna contributed to scientific understanding about life on Earth.	Discuss how the geological timescale incorporates the discovery of the Ediacaran Fauna.	Conduct some research to allow you to analyse how the discovery of the Ediacaran Fauna led to collaboration between different scientific disciplines.	
Conduct some research to find out about radiometric dating and explain how it has improved our understanding of the fossil record.	Mary Anning was an early palaeontologist and fossil collector. Conduct some research and write a paragraph that discusses her contribution to our understanding of life on Earth.	Analyse how scientific knowledge led to the decision to heritage list the sites where Ediacaran Fauna was discovered.	
Construct a representation of the geological time periods to scale, adding in your information from step 2.	Work with a partner to identify any interesting patterns or trends in your scale from step 3.	Write a paragraph that discusses any trends or patterns that you observe on your scale from step 3.	Science how-to p. 240
Select one of your proposals from step 2 and create a draft version.	Brainstorm how you could use digital technologies to enhance your presentation. Incorporate these into your final version if appropriate.	Work with a partner to review and provide feedback on each other's presentation. Incorporate any feedback as appropriate.	Science how-to p. 255

Palaeontologists have suggested that these ones may have been preserved because predators had not yet evolved to eat the bodies of the organisms buried in the sand.

The Ediacaran Fauna are the oldest-known multicellular organisms on Earth. They are so important, they have given their name to a geological time period. Before their discovery, the first evidence of complex life was from the Cambrian period (538–486 million years ago). Life in the Cambrian was even more complex, with many fossils of many different species with hard body parts.

Figure 6.33: ▶ A fossil of Dickinsonia, one of the most common of the Ediacaran Fauna



Figure 6.34: An artist's ▶ impression of Dickinsonia



7.0 Energy

Energy is one of the most useful things. We can use energy to make things happen or to create a change. Imagine an aeroplane climbing high. It uses energy stored in the fuel to power the climb. After the plane reaches a certain height, a person jumps out of it. They fall faster and faster as the gravitational energy of being high above the Earth is turned into movement, or kinetic energy. After their parachute opens, their speed is reduced as the kinetic energy is changed into other forms of energy until they finally land safely.

Learning Ladder

The Learning Ladder for each chapter maps the Science Understanding, Science as a Human Endeavour and Science Inquiry strands that will be covered. Each ladder has five levels of progression, called steps. To climb the ladders, you need to develop fluency at each step. This will help you develop the ability to complete tasks that are more complex.

5	I can evaluate household energy usage and propose ways to decrease energy consumption and waste	I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations
4	I can analyse energy changes in terms of energy efficiency and household consumption	I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues
3	I can represent energy transfers and transformations in simple systems	I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances
2	I can differentiate between energy transfer and energy transformation	I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society
1	I can identify and classify different forms of energy	I can recognise scientific problems and solutions	I can identify socio-scientific issues
Steps in progression	Physical science: Energy	Nature and development of science	Use and influence of science
	Science understanding	Science as a human endeavour	



Figure 7.1: Energy can change form, and be transferred from one object to another, allowing us to experience amazing things!

I can analyse processed data for patterns, trends, relationships and anomalies	I can communicate scientific findings and arguments for specific purposes to specific audiences	5
I can identify and discuss trends and/or patterns in a range of dataset representations	I can use digital technologies to organise and communicate data and information	4
I can process data by using mathematical relationships and/or constructing graphs	I can prepare a variety of representations to communicate ideas and findings	3
I can organise and display data using tables, keys and/or models	I can select appropriate formats to communicate ideas and findings	2
I can identify data from tables and graphs	I can identify scientific terminology used to communicate information	1
Processing, modelling and analysing	Communicating	Steps in progression
Science inquiry		

7.1 ▶ Types of energy



Figure 7.2: A rollercoaster ride involves many different types of energy.

Learning intention

At the end of this lesson, I will be able to identify different forms of energy and classify them as kinetic or potential.

Key terms

energy: the ability to do work

kinetic energy: the energy of movement

mass: the amount of matter that a physical body contains

motion: the change in position of an object over time

potential energy: stored energy; has the ability to cause movement

transfer: the movement of energy from one place or object to another

transform: the change of energy from one form to another

work: when a force applied to an object causes the object to move

Investigation 7.1

Rolling balls, p. 347

Key idea: Matter and energy

Imagine you are on a rollercoaster that is climbing slowly up the track. You hear the clicking of the gears as you move further from the ground. At the highest point, your heart is pounding. For a moment you are still. Then, you drop down the other side and your speed increases quickly, pulled by gravity. As you plummet down, you feel weightless and then heavier at the bottom as the rollercoaster curves back up again, over and over, until the ride stops. You just experienced many different types of energy in a single ride! **Energy** is defined as the capacity of an object to do work. Energy can make things happen or create a change.

A moving object has kinetic energy

The **kinetic energy** of an object such as a moving rollercoaster is the energy that it has because of its **motion**. The amount of kinetic energy a moving object has depends on its **mass** and its speed (see Figure 7.3).

Many common types of energy are classified as kinetic energy because they involve the movement of particles, even if the motion cannot be seen. In sound energy, the particles in the air or another substance vibrate, or move. Thermal energy is the vibration of particles in objects as they are heated. Particles vibrate more when the thermal energy is higher.

Kinetic energy can be **transferred** from one object to another. It can also be **transformed** or changed into other types of energy. This will be discussed further in Sections 7.2 and 7.3.

30

The bicycle and the truck are travelling at the same speed, but the truck is heavier, so it has more kinetic energy.



30



10



4

Both people weigh the same amount, but the one who is moving more quickly has more kinetic energy.

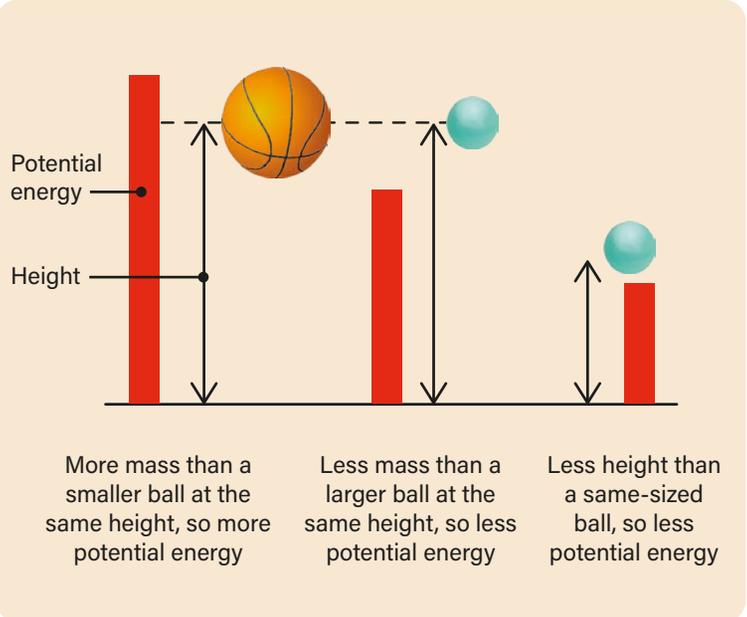


▲ **Figure 7.3:** What type of energy do moving objects have?

Potential energy is stored until release

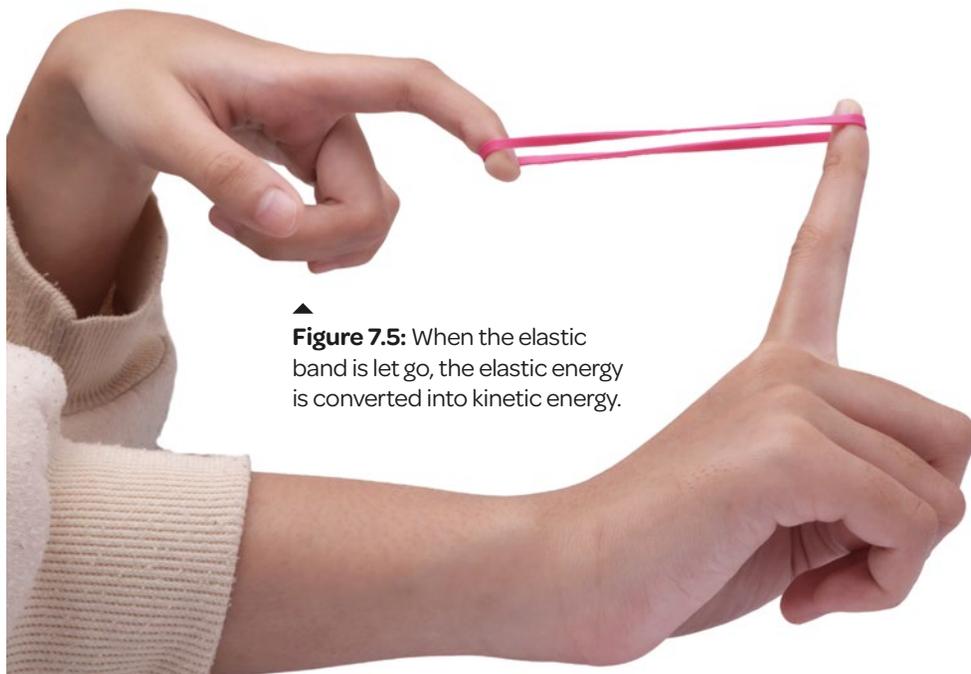
Potential energy is stored energy that can be used to do **work**. This work might be shooting an arrow or making a fire to cook food. There are different ways that energy can be stored and released to do work.

Gravitational potential energy is the energy an object has because of its position above the ground (see Figure 7.4). An object lifted up high has the potential to do work. When lifted up, an object with more mass has more gravitational potential energy than an object with less mass. When an object falls because of gravity, it moves and gains speed, and gravitational potential energy is transformed into kinetic energy.



▲ **Figure 7.4:** The higher above the ground an object is, and the greater its mass, the more gravitational potential energy it has.

Elastic potential energy is the energy stored in an object such as a spring or an elastic band when it is pulled back. When you let it go, the elastic band returns to its original shape, and the stored elastic potential energy is transformed into kinetic energy. The stronger the elastic band or spring, the greater its potential to store energy. Also, the more an elastic object is stretched or compressed, the more potential energy it stores.



▲ **Figure 7.5:** When the elastic band is let go, the elastic energy is converted into kinetic energy.

Chemical potential energy is the energy stored in the bonds between atoms in a substance. Chemical reactions break the bonds and release the energy that is holding them together. One very common chemical reaction is combustion, such as when wood burns in a campfire. Heat, light and sound energy are released when the bonds between the atoms that make up the wood are broken and rearranged.

Nuclear potential energy is different from chemical energy because it involves a change to the nucleus of an atom rather than to the bonds that hold atoms to other atoms.

When a nuclear reaction takes place, an enormous amount of energy is released from the nucleus of an atom, which can cause a chain reaction of energy release. When nuclear reactions are not properly controlled, the results can be explosive (see Figure 7.6).



Figure 7.6: The uncontrolled release of stored nuclear potential energy causes a devastating explosion.

There are different types of kinetic energy and potential energy

Table 7.1 shows some common types of kinetic and potential energy.

Table 7.1: Common types of kinetic and potential energy

Energy type		Description
Kinetic	Motion	The energy that an object has because of its movement (change in position over time)
	Thermal	The motion or vibration of atoms and molecules in a substance or object that is being heated
	Light	A form of electromagnetic radiation emitted by hot objects; it is usually visible or other types of light
	Sound	The vibration of particles that can be detected by the ear
	Electrical	The energy gained from the movement of electric charges like electrons
Potential	Gravitational	The energy stored in an object because of its position above the ground
	Elastic	The energy stored in an object when it is stretched or deformed
	Chemical	The energy stored in the bonds between atoms, released as heat, sound or light during chemical reactions such as burning
	Nuclear	The energy stored in the nucleus of atoms; it may be released quickly as a nuclear explosion or controlled slowly as a nuclear reaction

Learning Ladder

Energy

- Identify the type of energy that exists in each situation below and classify it as potential or kinetic.
 - An arrow pulled back in a bow
 - A glowing light bulb
 - An apple
 - Listening to music
- Describe the difference between energy transfer and transformation, using an example for each.
- When the rollercoaster is falling, describe the energy transformations that are taking place at:
 - the top of the ride.
 - halfway down the slope.
 - the bottom of the ride.

Nature and development of science

- Select which of the following would be a reasonable solution when a test rollercoaster is not reaching the top of the second hill in the system.
 - Increase the height of the first slope
 - Increase the height of the second rise
 - Reduce the mass or weight of the ride
- Making a rollercoaster would require many experts to work together. Propose why collaboration is important.
- Use your knowledge of energy to explain why sound energy is classified as kinetic energy.
- Discuss why scientists decided to classify energy into two main types.
- Analyse how a chemist and a physicist may collaborate to develop knowledge of energy.

Communicating

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- Identify and define four key scientific words you would use to communicate the concept of energy to another person.
- Propose an appropriate format for communicating what energy is to a group of primary school students. Give one reason why you chose this format.
- Construct an infographic to represent the information communicated in Question 2.

Key idea: Matter and energy

Research and compare the amount of potential energy stored in a stretched elastic band (elastic potential) and in a litre of petrol (chemical potential).

Success criteria

- I can define energy, including potential and kinetic.
- I can describe examples of energy.
- I can classify examples of energy as kinetic or potential.

7.2 ▶ Energy transfer

Learning intention

At the end of this lesson, I will be able to:

- identify conduction, convection and radiation as different ways that energy can be transferred
- distinguish between and explain examples of conduction, convection and radiation.

Key terms

conduction: the transfer of energy through a substance

conductor: a substance that allows the transfer of energy

convection: the transfer of energy by movement of a liquid or gas

heat: the flow of thermal energy between objects

insulator: a substance that resists the transfer of thermal energy

matter: a substance that has mass and takes up space

radiation: the transfer of energy that does not require contact with matter

thermal energy: energy in a system or object that is responsible for its temperature

Investigation 7.2A

Conduction: heat energy transfer in a solid, p. 348

Investigation 7.2B

Convection: heat energy transfer in a liquid, p. 349

Key idea: Matter and energy

Heat is a transfer of thermal energy. The terms 'heat' and 'thermal energy' are sometimes used interchangeably. Thermal energy can be transferred in three ways: by conduction, convection and radiation. Heat always moves towards the object with less energy. In other words, thermal energy is always transferred from hot to cold.

Conduction is the transfer of energy through materials

Energy moves through solids by **conduction**. All the particles in the solid are vibrating in place. When heated, the particles gain energy and vibrate even more. As the particles bump into neighbouring particles, energy is transferred along the object. Heat moves through the solid (see Figure 7.7).

Some solids transfer thermal energy better than others. Substances that transfer heat well are called **conductors**. Metals are among the best conductors. Non-metals are usually poor conductors of heat and are known as **insulators**. Plastic, wood and rubber are insulating materials. This is why rubber thongs protect your feet from hot sand.

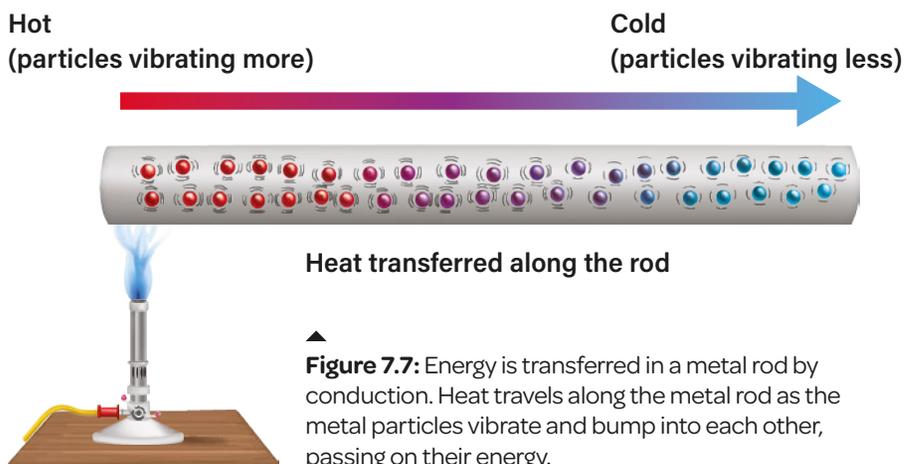


Figure 7.8: A variety of materials ▶ can be used to insulate our homes. Why do you think spray-foam material is one of the most effective insulators for a roof space?



Figure 7.9: Convection currents can be seen in lava lamps, which contain wax in a transparent liquid. The bulb in the base heats the wax, which causes a convection current.



Convection transfers energy when particles move

Thermal energy is transferred when particles in matter move by **convection**. Particles in liquids and gases can flow freely past one another, rather than just vibrating in place as they do in solids. When a liquid or gas is heated, particles move to take the place of particles with less heat. If a liquid is heated from underneath, particles move from the heat source at the bottom towards the top where the liquid is cooler. The cooler particles are then pushed downwards and their thermal energy increases, which causes them to rise again. This continuing pattern of movement is called a convection current. The same pattern of movement occurs with gases.

Convection currents are due to density differences. When a liquid or gas is heated, the particles move further apart from each other, causing the substance to expand and decrease in density. This causes it to rise into cooler areas. The denser cold liquid or gas falls into the warm areas, triggering the convection currents that transfer energy from place to place.

Convection explains why hot-air balloons rise, how lava lamps work (see Figure 7.9), and why it is often hotter upstairs than downstairs in a two-storey house.

Radiation transfers heat through a vacuum

Radiation is when heat energy is transferred from one place to another without **matter** moving or vibrating. Radiation travels as electromagnetic waves. This is how the heat of the Sun travels through the vacuum of space to Earth. Many types of energy can be transferred by electromagnetic radiation, such as visible light and microwaves. Heat energy, or infrared radiation, causes objects to gain thermal energy and heat up when placed near a fire or left outside on a sunny day. Infrared heaters transfer thermal energy throughout a room by radiation.

Learning Ladder

Energy

- 1 True or false?
Thermal energy is a type of potential energy because it is not an object in motion.
- 2 Describe how thermal energy is transferred in solid, liquid and gaseous substances.
- 3 Identify and explain the types of energy transfers (conduction, convection, radiation) in each of the following systems.
 - a When stirring coffee, the spoon gets hot.
 - b Warm air over hot sand rises, whereas cooler dense air blows in from the ocean.
 - c The sun heats a rock that becomes too hot to sit on.
- 4 Heat is applied to a wooden object and a metal one.
 - a Propose which object will transfer energy better by conduction.
 - b Describe how you could measure the observed change in each case.

Use and influence of science

- 1 Identify an issue caused by the sun heating dark-coloured roads.
- 2 Describe an example of how we build structures to reduce heat build-up in our community.

Communicating

p. 255

- 1 Identify the three key types of energy transfer explained in this section.
- 2 Describe an appropriate communication format to explain and compare the scientific ideas of conduction, convection and radiation.
- 3 Prepare an example of the communication format proposed in Question 2.
- 4 Develop an animation to communicate the meaning of conduction, convection or radiation.
- 5 Present your animation to peers and answer any questions they ask.

Key idea: Matter and energy

A metal coffee cup gets very hot. Use your understanding of matter and energy to propose a solution to this problem.

Success criteria

- I can classify heat transfer, including convection, conduction or radiation.
- I can explain the difference between convection and conduction with reference to states of matter, energy and particle theory.

7.3 ▶ Energy changes and efficiency



Figure 7.10: Energy transfers and energy transformations take place during cooking. Chemical potential energy in gas is burnt to produce thermal energy. The thermal energy is transferred to the frying pan and then to the food being cooked.

Learning intention

At the end of this lesson, I will be able to:

- identify a system and the energy transfers and transformations within it
- analyse the energy changes in terms of energy efficiency.

Key term

efficiency: a measure of how much useful energy is produced compared to how much is input into a system

energy input: the total amount of energy being put into a system

energy output: the total amount of energy coming out of a system

joules: the unit for energy, represented by the symbol J

pendulum: an object suspended at the end of a string that swings back and forth

system: a set of simple things that work together to perform a function

useful energy: the energy output from a system that is able to be used for a purpose

Investigation 7.3

Energy transformations, p. 350

Key idea: Matter and energy

All energy on Earth originally comes from the Sun. Nuclear reactions in atoms power the Sun, and this energy is transformed from nuclear potential energy into light and heat. The Sun then radiates an enormous amount of light and heat energy into space in all directions. Only a small amount of this energy is transferred to Earth, where it is then stored, released, transferred and transformed over and over again.

Energy causes change in systems

When several simple things work together to perform a function, this is called a **system**. Energy transfers and transformations cause change in systems. These changes are happening all the time around us.

Energy *transfers* happen when the energy in one object is transferred to another object, which causes observable changes in those objects. An example is when you fry eggs: thermal energy from the stove is transferred to the frying pan, which heats up to cook the eggs. It is still thermal energy, but it has been transferred from the stove to the pan and to the eggs. The transfer of energy usually involves more than one object.

Energy *transformations* happen when a form of energy is changed to a different form of energy. This also causes change in the system. An example is when light bulbs change electrical energy to light and heat energy. Another example is when the elastic potential energy of a stretched rubber band changes into kinetic energy when it is released. The rubber band is a single object that experiences two types of energy: elastic potential energy transformed into kinetic energy. The rubber band flying across the room is the observable change in the system.

Devices can be used to transfer and transform energy

How did you get to school today? Maybe you came in a car or bus; maybe you rode a bicycle or walked. Your travel to school involved a transformation of energy. Chemical potential energy (the petrol in the car or the food you ate) was transformed into kinetic energy (causing the motion of the car or of your legs). We use many devices to transform energy. For example, televisions transform electrical energy into light and sound energy, and kettles transform electrical energy into thermal energy.

Imagine that you threw a book, and it fell to the ground with a bang (see Figure 7.11). How many energy transfers and transformations would happen? Recall the many different forms of energy from Table 7.1 in Section 7.1. In a suitable system, any one of these forms could be transformed into one of the other forms or the energy transferred from one object to another.

Figure 7.11: How many energy transformations are happening here?

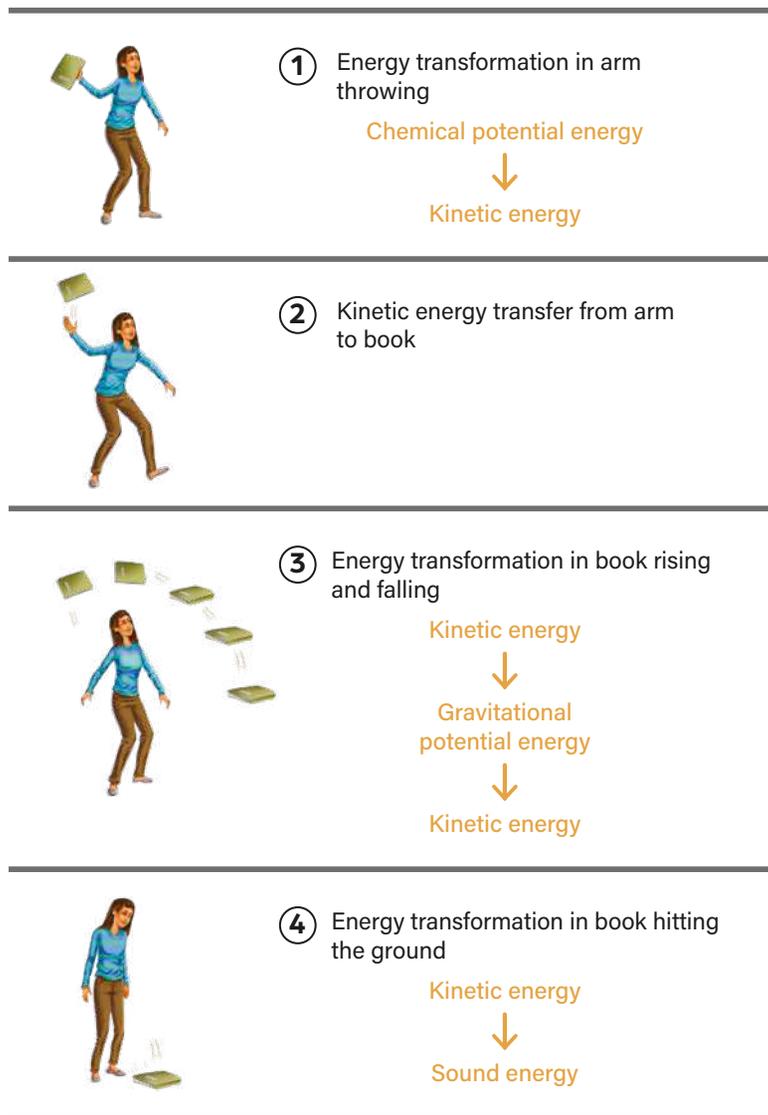


Figure 7.12: A bicycle is a system that transforms the energy in your muscles into energy for movement.



Flowcharts can be used to represent energy transformations

An apple can grow because of light and heat energy from the Sun, which it transforms and stores as chemical potential energy. You eat the apple, and your body transforms the chemical potential energy in the apple into kinetic energy for movement such as walking. These energy transformations can be displayed on a flowchart. Flowcharts clearly show where energy has come from, what it is doing and where it goes.

Energy is wasted during transformation and transfer

When energy is transferred or transformed, some of it is lost or wasted during the change. In the example of a television, energy is not only used to produce a picture of visible light, but is also transformed into heat, which is lost or transferred to the screen of the TV and into air. This means that devices are inefficient, or wasteful. **Efficiency** is a measure of how much **useful energy** is transferred or transformed during a change. An efficient device will have a high amount of useful energy and little waste. An inefficient device will have a low amount of useful energy and a high amount of energy wasted.

Figure 7.14 shows two light bulbs: one old globe, which is inefficient, and a new, much more efficient LED globe. In this example, electrical energy is transformed to useful energy as light, while waste energy is lost as heat. The amount of energy is shown in **joules (J)**, the unit for energy. You can see that the efficient LED light produces a much higher amount of useful energy.

Figure 7.14 also shows a simple Sankey diagram. Notice how the width of the arrows is related to the amount of energy. The **energy input** equals the total **energy output**, but the output splits into useful (light) and waste (heat) energy. Some devices will produce different types and numbers of energy outputs, which can be shown on a Sankey diagram with more arrows, like the example of the fan in Figure 7.15.

▼ **Figure 7.13:** Energy transformations taking place from growing food to using energy from the food

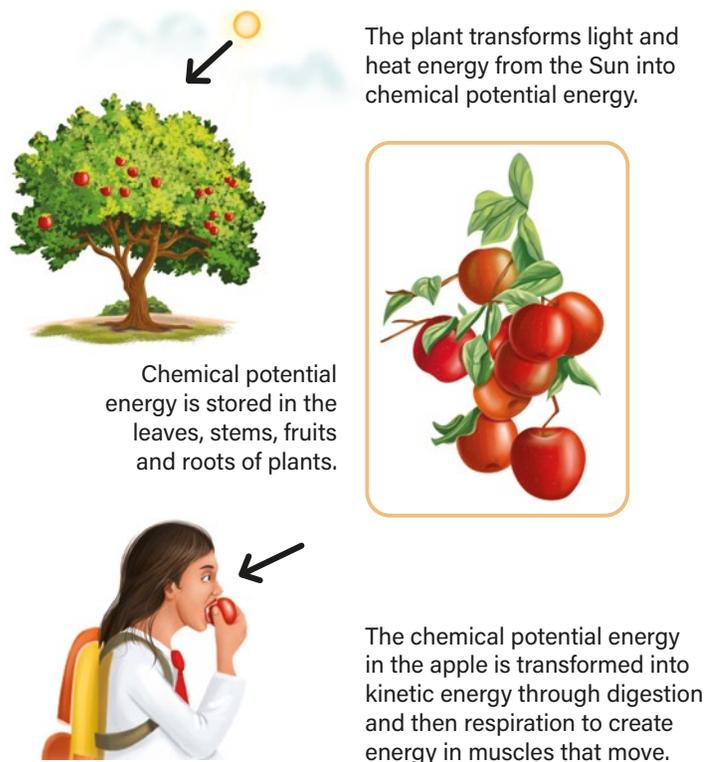


Figure 7.14: LED light bulbs are much more efficient and produce less waste energy as heat than old filament or incandescent bulbs.

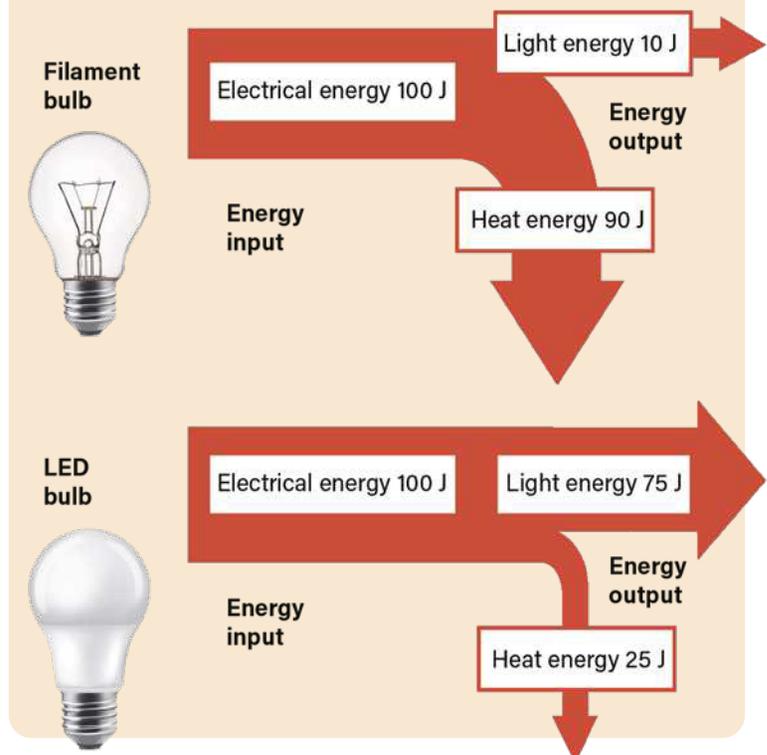
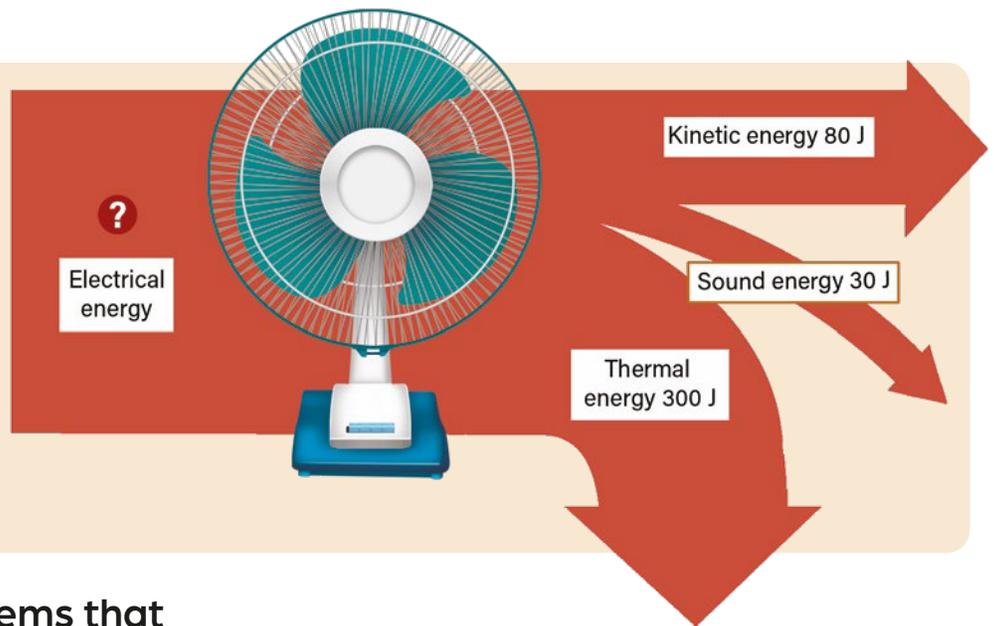


Figure 7.15: A fan produces both useful and waste energy. Can you identify how much electrical energy is being input, and how much waste energy there is in total?



Cars are complex systems that transform and transfer energy

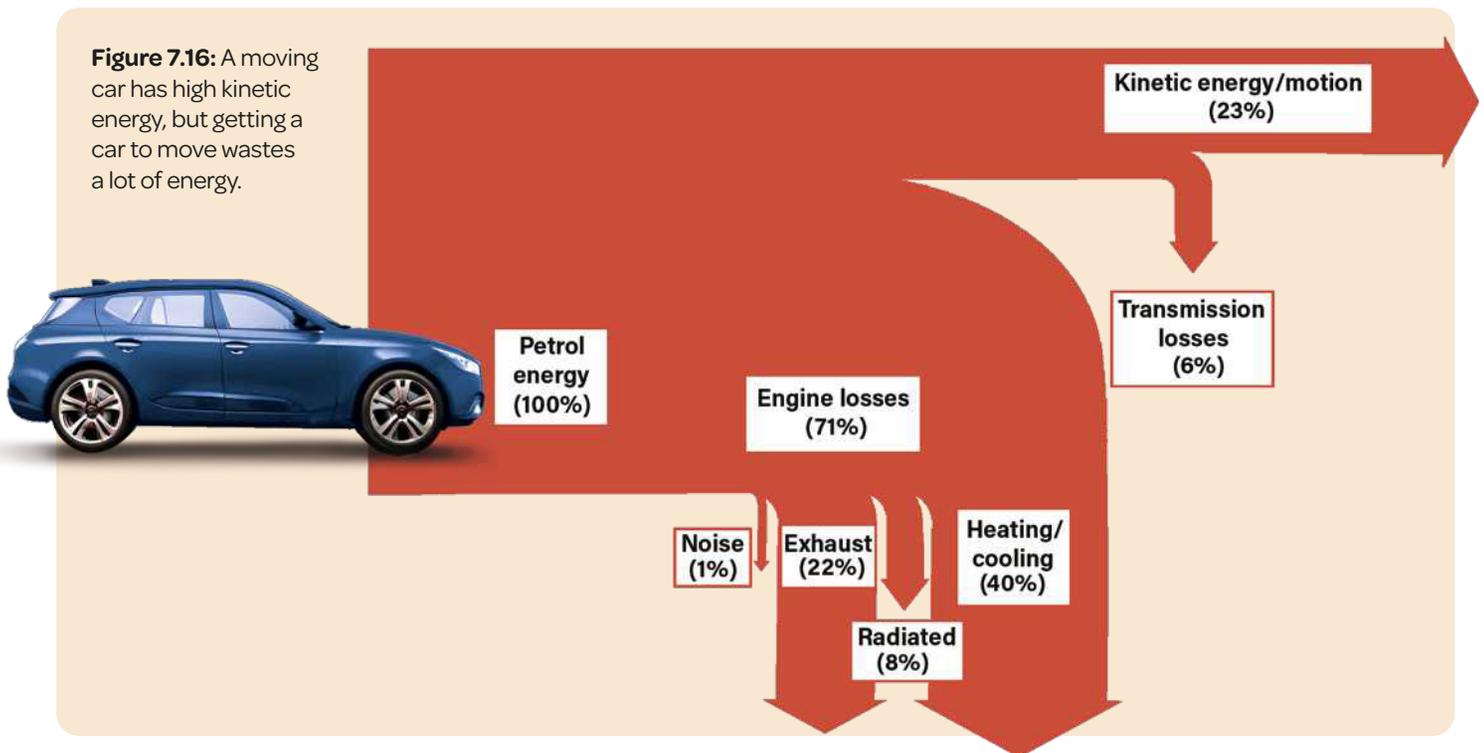
Cars transfer and transform energy in many ways. In a petrol-powered car, the fuel burns in the engine to produce hot gases that cause pistons to move up and down, which in turn spins the engine. The engine is connected to the gear box and then to the wheels. Overall, the main energy transformation is:

Chemical potential energy (petrol)
 → Kinetic energy (motion)

But along the way, there are many energy transfers. For example, kinetic energy in the engine is transferred

to the gearbox, and then to the wheels, all of which move or turn, causing the car to move forward. At each stage, energy is lost. As you can see in Figure 7.16, only 23 per cent of the original chemical potential energy of the petrol is transformed and transferred into kinetic energy. Much of the energy is wasted as heat, lost through the exhaust or radiated from the engine. A large amount is used for heating and cooling the car, including to stop the engine overheating. Some energy is also wasted in transmission losses such as friction when wheels push against the road and through air resistance.

Figure 7.16: A moving car has high kinetic energy, but getting a car to move wastes a lot of energy.



Pendulums swing and transform energy

A **pendulum** is an object suspended at the end of a string that swings back and forth. Pendulums transform energy with each swing. A simple ball at the end of a string attached to a pole (see Figure 7.17a) is a pendulum. As the pendulum swings back and forth, energy is transformed between potential and kinetic energy. At point 1, before the pendulum is released, it has a maximum gravitational potential energy. After release, the gravitational potential energy is transformed to kinetic energy as the ball falls and swings.

At point 3, the lowest point, the ball has maximum kinetic energy and minimum gravitational potential energy. As the ball rises, the kinetic energy is transformed back into gravitational potential energy until it reaches point 4. These energy transformations are what keeps the pendulum swinging.

As the pendulum swings, it gradually slows down. This is because it loses a little bit of energy on each swing by transferring it to the air in the form of kinetic energy. The movement of the string causes it to rub against the top of the pole, creating a small amount of thermal energy. These small energy losses mean the pendulum won't swing as high each time and will eventually stop, resting at point 3.

A pirate ship ride at a funfair (Figure 7.17b) is just a really big, fun pendulum! The ship normally starts at the bottom as people get on board, and a motor is used to start the ship moving, until it is swinging. Can you describe the energy transformations as the ride starts to swing?

Figure 7.17: A simple ball at the end of a string and a pirate ship ride at a funfair are both examples of pendulums.

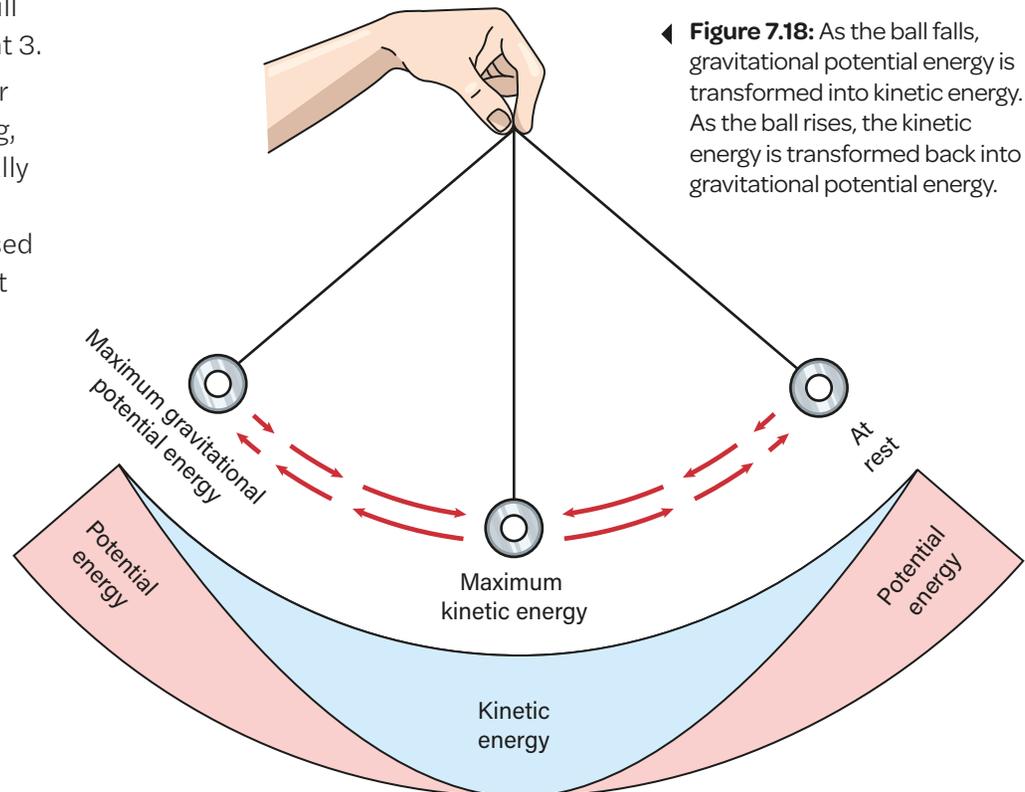
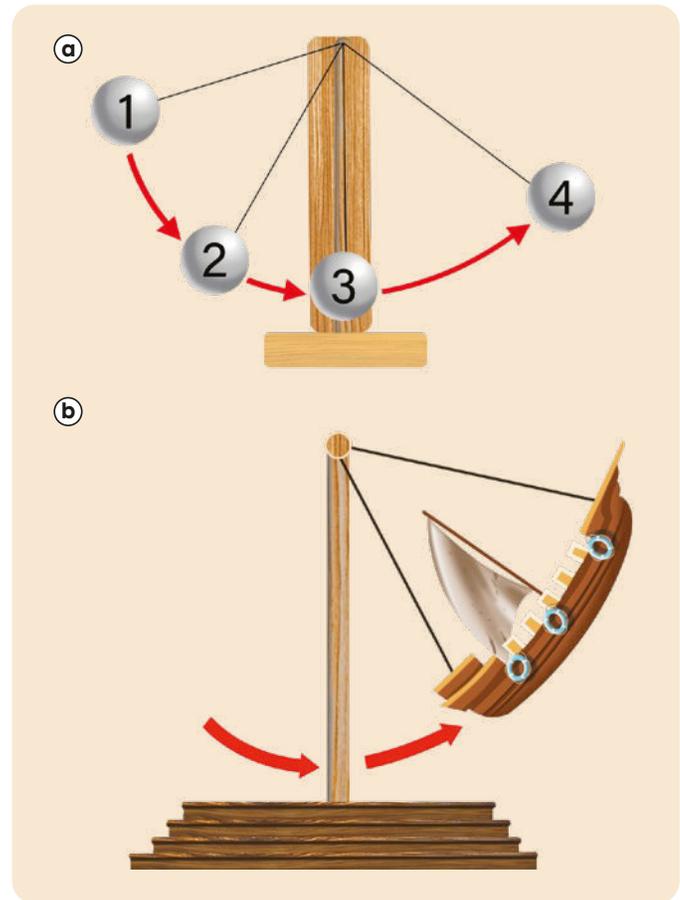


Figure 7.18: As the ball falls, gravitational potential energy is transformed into kinetic energy. As the ball rises, the kinetic energy is transformed back into gravitational potential energy.

Learning Ladder

Energy

- Propose the main forms of energy related to each of the following and give a reason for your answer.
 - Standing on a tightrope, 10 metres off the ground
 - An arrow ready for release from a bow
 - A fireworks display
 - A pendulum at the bottom of its swing
- Categorise the following as an energy transfer or transformation (or both) and justify your answer.
 - Kicking a ball
 - A candle burning
 - Hitting a drum
 - A pendulum swinging
 - A car crash
- Complete the following table to show the energy during the swing of a pendulum system. The position number relates to positions on Figure 7.17a.

Position during swing (Figure 7.17a)	Kinetic energy	Gravitational potential energy
1	zero	maximum
2		
3	maximum	
4		

- A pendulum will not swing forever.
 - Explain what 'efficiency' means.
 - In relation to efficiency, explain why the pendulum eventually stops.
 - Propose reasons why a pirate ship ride has a motor that adds energy while the ride is going.

Nature and development of science

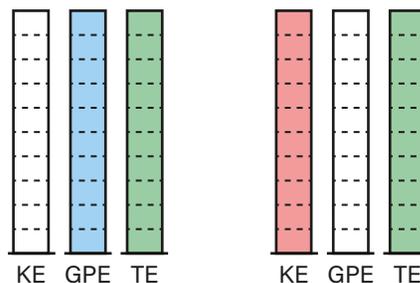
- Cars consume large amounts of energy.
 - Propose a scientific problem related to cars being inefficient.
 - Propose one potential solution to the problem identified in part a.
- Propose how different types of scientists could work together to design a more efficient car.

Processing, modelling and analysing p. 240

- For each type of light bulb shown in Figure 7.14, identify and state the total energy input and total energy output for each bulb. Energy input is shown (e.g. 100 J), and energy output is, for example, 90 plus 10 = 100 J.
- Use data from Figure 7.16 to construct a table of data showing the energy input and output from a petrol car.
- Construct a Sankey diagram for the following energy transformations.
 - A hair dryer uses 750 J of electrical energy, and produces 125 J of kinetic energy, 150 J of sound energy and 550 J of thermal (heat) energy.

- A child at the top of a slide has 1000 J of gravitational potential energy. As they slide down, they have 900 J of kinetic energy. 25 J is lost as sound, and 100 J is lost as heat.
- One hundred per cent of the chemical potential energy from a cyclist is transformed to 45 per cent forward motion of the bike (kinetic energy), 25 per cent body movements including pedalling (kinetic energy of the person), 18 per cent heat from the person's body, 10 per cent heat through the bike and 2 per cent sound energy.

- The following graphs show the kinetic and potential energy at different points in a pendulum swing. The total energy is the amount of kinetic and potential energy added together. The first graph shows the energy at position 1 in Figure 7.17a. Graph 2 shows the energy at position 3.



KE = Kinetic energy

GPE = Gravitational potential energy

TE = Total energy

- Construct two graphs that show the energy at positions 2 and 4 of the swing.
 - Identify and discuss the trend in energy efficiency observed across the four positions.
- Analyse and compare Figures 7.14, 7.15 and 7.16 and describe the similarities between each Sankey diagram.

Key idea: Matter and energy

Most cars burn petrol as their source of energy. With reference to energy transfer and transformation, outline why more car makers are designing vehicles that are powered by alternative energy sources.

Success criteria

- I can describe the difference between energy transfer and energy transformation.
- I can give examples of an everyday energy transformation and transfer in systems.
- I can analyse efficiency using examples and representations.

7.4 ▶ First Nations energy changes and fire

Learning intention

At the end of this lesson, I will be able to:

- describe the fire starting methods used by First Nations Peoples and explain how these relate to energy transfer and energy transformation
- outline the uses and importance of fire to First Nations Peoples.

Key terms

ember: a hot, glowing piece of wood produced during fire starting

fire: a self-sustaining chemical reaction between wood (or other material) and oxygen in the air that releases chemical energy as heat and light

friction: the force between two objects or surfaces when they push against each other

pyrophytic: plants that have adapted to fire

tinder bundle: a small amount of fine dry grass, animal dung, leaves or other matter used to start a fire

Key idea: Matter and energy

Australia's First Nations Peoples have used the energy in fire for many purposes, including agriculture, cooking, ceremonies and caring for Country. Managed burning of Country generates and renews **pyrophytic** vegetation, which has adapted to fire, creating pathways and new growth to attract animals that can be hunted for food. First Nations Peoples have developed tools and techniques that use energy transfer and energy transformation to start and manage fires. Their knowledge has been passed down through generations and is still used today to care for Country.

Fire is energy transformation

Fire is a chemical reaction that releases energy. When a fire burns, the chemical energy in a fuel such as wood is transformed into heat and light. To start a fire, a certain amount of initial energy, usually as heat, must be produced. Once enough energy is produced, the fire will start to burn and become self-sustaining – that is, it burns without further energy input.

Fires are started by friction

To start a fire, a tool is used to generate heat. This usually involves **friction**, a type of force that is produced when two objects are rubbed or hit together. The friction creates a small hot burning **ember** or a spark. The ember or spark is then placed into a **tinder bundle**. The material used as tinder may include dry grass, coconut fibre, dried kangaroo dung or powdered eucalyptus leaves. After the ember is placed into the tinder, it is blown until a flame is produced. Now there is fire!

In most cultures, there is typically one way to start fires. But First Nations Peoples may use up to four methods: fire drill, fire saw, fire plough or percussion. Some Aboriginal and Torres Strait Islander Peoples used at least three methods. This means that fire was created in different ways in different conditions or locations, using whatever resources were available at the place and time. Many Aboriginal and Torres Strait Islander Peoples also use a pinch of sand to increase the friction between two pieces of wood when creating an ember.

The fire drill and fire saw methods are most commonly used

The *fire drill method* for starting a fire requires two basic tools: a flat piece of soft wood to use as a base, and a long stick to be used as the drill stick. The drill stick can be either hard or soft wood. The blunt end

Figure 7.19: The fire drill technique produces a hot ember that can start a fire.





Figure 7.20: Fire has been used by First Nations Peoples for tens of thousands of years, including to care for Country.

of the drill stick is pushed down into a small indentation or hole in the base. Enough force must be applied downwards to increase the friction. The stick is twirled quickly between both hands. The kinetic energy of the hands is transferred to the spinning stick. Rubbing the stick against the base transforms the kinetic energy into heat. The base has a small gap near the indentation that collects hot sawdust from the friction. This sawdust forms a glowing ember, which is then used to ignite the tinder. This method is common in northern and coastal regions of Australia.

The *fire saw method* uses a sawing motion, rather than spinning, to create friction. A small branch is split, and tinder is placed into or near the end of the split. A sharp-edged piece of hardwood is used to ‘saw’ back and forth in the split, creating friction to make an ember that ignites the tinder. Often the saw is a boomerang, wooden knife, coolamon or other tool that has other uses, too. In central Australia, the saw was sometimes the edge of a spear thrower, while the base was a soft shield.

The fire plough and percussion methods

The *fire plough method* involves rubbing the end of a stick back and forth in the groove cut into a flat piece of wood. This method is generally only used in north-western Australia near Rubibi (Broome) and Wender (Eighty Mile Beach).

The *percussion method* involves hitting a piece of flint stone against a piece of ironstone to create friction, which causes tiny pieces – or shards – of the ironstone to split off. These shards, which have been heated to a high temperature by the friction, are then placed on a tinder bundle to ignite it. This method is used by some groups in South Australia who have access to flint stone.

Learning Ladder

Energy

- 1 Identify the main forms of energy involved in creating fire using the four methods outlined.
- 2 For each of these fire starting methods, give an example of energy transfer and energy transformation.
- 3 Draw a flowchart to represent the energy transfer and energy transformations using the fire drill as an example. Include as many steps as you can.

Use and influence of science

- 1 Identify one reason why fire was important to First Nations Peoples.
- 2 Suggest how First Nations Peoples’ knowledge of fire may have affected their society.
- 3 Explain how First Nations Peoples’ scientific knowledge of fire impacted the environment.
- 4 First Nations Peoples burnt the land in some areas to reduce the fuel that fed bushfires. This practice helped to clear undergrowth in forests and to maintain grasslands. After colonisation, this practice declined and forests became more dense. Discuss the impact this change has had on fires in Australia today.
- 5 Analyse how the communication of First Nations Peoples’ knowledge of fire has shaped how we manage land in Australia today.

Communicating

p. 255

- 1 Select and define six key words from this section that you were not familiar with before reading about this topic.
- 2 Propose a format that could be used to communicate how to start a fire to people who are camping but have no matches. Outline why you selected this format.
- 3 Construct diagrams to communicate each of the four ways of starting a fire described.

Key idea: Matter and energy

Research the local Traditional Owners in your area to find out how they traditionally made fire. Discuss how this relates to energy transfer and energy transformation.

Success criteria

- I can describe fire starting methods used by Australia’s First Nations Peoples.
- I can explain the energy transfers and energy transformations in fire starting methods.
- I can outline the uses and importance of fire for First Nations Peoples.

7.5 ▶ Appliance efficiency

Learning intention

At the end of this lesson, I will be able to:

- explain star ratings for appliances in relation to efficiency
- compare energy transformed over time in appliances.

Key terms

energy consumption: the amount of energy used, measured in kilowatt-hours (kWh)

energy tariff: the price of electricity purchased from the electricity company, in cents

star rating: a rating for comparing the efficiency of different appliances

Investigation 7.5

Comparing energy in appliances, p. 351

Key idea: Matter and energy

Energy-efficient appliances are cheaper to run than conventional appliances and are better for the environment.

Light bulbs are becoming energy efficient

Old incandescent light bulbs are very inefficient, wasting 90 per cent of their energy as heat. Halogen lamps are about 10–20 per cent more efficient than incandescent bulbs, so governments around the world started phasing out the less efficient bulbs in the mid-2000s.

Compact fluorescent bulbs and LED lights use even less energy, and the Australian Government began phasing them in, to replace halogen bulbs, in 2020. By phasing out these older types of light bulb, we will pay less to light our homes and use less energy. This will also reduce the amount of wasted energy as we change to more renewable energy supplies.

Energy-efficient devices have star ratings

Many governments have enacted laws requiring minimum standards for appliances. A lot of scientific research has been directed at improving the energy efficiency of appliances and systems.

Australia requires energy efficiency **star ratings** to be applied to most new appliances such as fridges, washing machines, televisions and pool pumps! These star ratings help us to purchase devices that will waste less energy, reduce greenhouse gas emissions and save on energy bills.

More efficient products have more stars

Energy-rating labels include useful information:

- A star rating allows you to compare products – the more stars an appliance has, the more efficient it is. Appliances are given a rating out of 10. New super-efficient models may be given up to 10 stars.
- **Energy consumption** information tells you how much electricity an appliance uses each year, in kilowatt-hours (kWh). One kilowatt-hour is how much energy the appliance uses in 1 hour.

If we know the energy consumption and the **energy tariff**, we can work out the estimated running cost of the appliance for a year by using the following formula:

$$\text{Annual running cost} = \text{total energy consumption (kWh)} \times \text{electricity tariff (dollars per kWh)}$$

For example, if a fridge has an energy consumption of 400 kWh and the electricity tariff is \$0.30 (30 cents) per kWh, then the estimated annual running cost is \$120.00 (400 kWh × \$0.30).

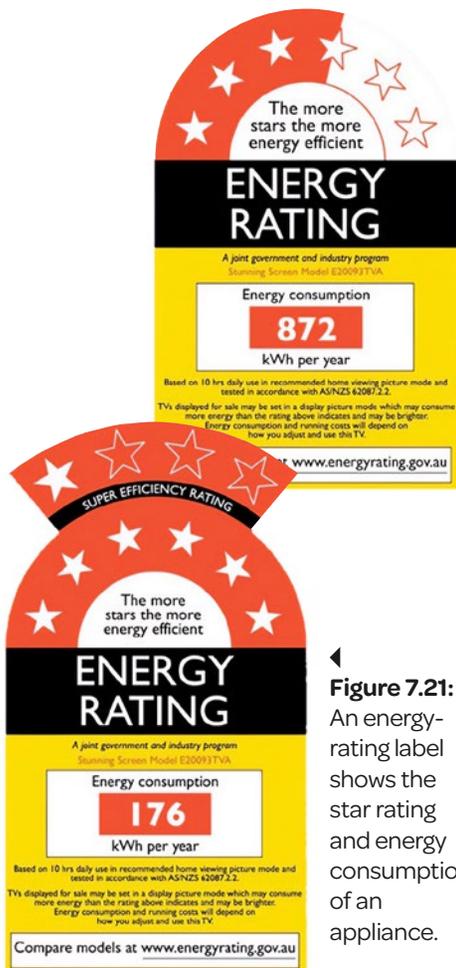


Figure 7.21: An energy-rating label shows the star rating and energy consumption of an appliance.

Similar appliances use different amounts of energy

In Figure 7.21 are two energy-rating labels, which we can compare to help us select the most efficient appliance. We need to compare appliances with similar features and make some assumptions about use, such as how many hours a day the appliance may be used. People use appliances in different ways.

Table 7.2 shows information for two 40-inch televisions with the same type of LCD (liquid-crystal display) screen being used for 10 hours a day. You can see that it costs nearly three times as much to run television 2 than to run television 1. Which one would you buy?



◀ **Figure 7.22:** Appliances in stores must display energy-rating labels.

Table 7.2: Comparing the efficiency of two televisions

	Television 1	Television 2
Star rating	8	3.5
One-year energy use	92 kWh	260 kWh
One-year running cost at tariff \$0.5478 (54.78 cents) per kWh	\$50.40	\$142.43
Ten-year running cost	\$503.98	\$1424.28

Learning Ladder

Energy

- 1 Identify different forms of energy in the example of the television shown in Figure 7.22.
- 2 Describe an example of an energy transformation and an energy transfer that occurs in the television.
- 3 Construct an energy-rating label to represent the energy use for the following refrigerator: star rating 7, energy consumption for one year 153kWh.
- 4 The energy tariff for the refrigerator in Question 3 is 35 cents per kWh. Calculate the cost of running the appliance for:
 - a 1 year.
 - b 10 years.
 - c 1 month.
- 5 If you were designing an energy-rating system for cars, propose the criteria you would use to assess their efficiency.

Use and influence of science

- 1 Outline an example of a social issue related to the science of energy efficiency.
- 2 Provide at least one reason why society is moving towards energy-efficient devices.
- 3 Discuss how knowledge of emissions such as carbon dioxide from fossil fuels that are used to make energy has led to the development of more efficient appliances.
- 4 Describe how a star rating based on scientific knowledge can help to change people's purchasing behaviour.
- 5 Analyse why scientific knowledge has led to government regulation of appliance efficiency.

Processing, modelling and analysing p. 240

- 1 Review Table 7.2 and identify the key data that would help you to decide which appliance to purchase. Justify your answer.
- 2 Construct a table (like Table 7.2) to compare the following clothes dryers. Assume an energy tariff of \$0.42.
 - a Clothes dryer 1: star rating 6, consumption 130kWh.
 - b Clothes dryer 2: star rating 7, consumption 138kWh.
- 3 Using the data organised in Question 2, assess which appliance you would purchase.
- 4 Review your response to Question 3 and, taking into account the following features, discuss how your decision may change.
 - a Clothes dryer 1: Has a sensor to turn off automatically when clothes are dry; fits 8.5kg of clothes.
 - b Clothes dryer 2: Does not turn off automatically when clothes are dry; fits 7.5kg of clothes.

Key idea: Matter and energy

Identify three appliances in your house with star ratings and record information about the energy used. Determine which appliance is most efficient.

Success criteria

- I can explain energy-rating labels and how they relate to the efficiency of appliances.
- I can compare energy transformed over time in appliances.

7.6 ▶ Household energy

Learning intention

At the end of this lesson, I will be able to describe how appliance choice and building design can optimise energy efficiency in a household and reduce energy waste.

Key terms

greenhouse gases: gases in the atmosphere that trap heat and contribute to the greenhouse effect, which warms the planet

heat pump: a device that moves heat from one place to another

insulation: a material or substance that does not allow heat to pass easily through it

optimise: make the most effective use of something

solar: from the Sun

Investigation 7.6

Thermal energy and colour, p. 353

Key idea: Matter and energy

In summer during a heatwave, there can be rolling blackouts when electricity is turned off in some areas for a period of time. This happens when there is not enough energy in the electricity grid to supply everyone. To ensure there is enough energy, we need to optimise its use by maximising energy efficiency while reducing energy waste.

Energy sources should be used efficiently

Efficient energy use is important if we do not want to run out of energy. If household electricity came mostly from renewable sources, we could reduce demands on non-renewable energy sources. Energy-efficient appliances also reduce energy use.

Solar energy is a common renewable energy source in Australia and is becoming more efficient and affordable.

- Solar thermal (heat) systems heat water.
- Solar cells absorb the Sun's energy and transform it to electrical energy. This energy can be stored in batteries for use at night.

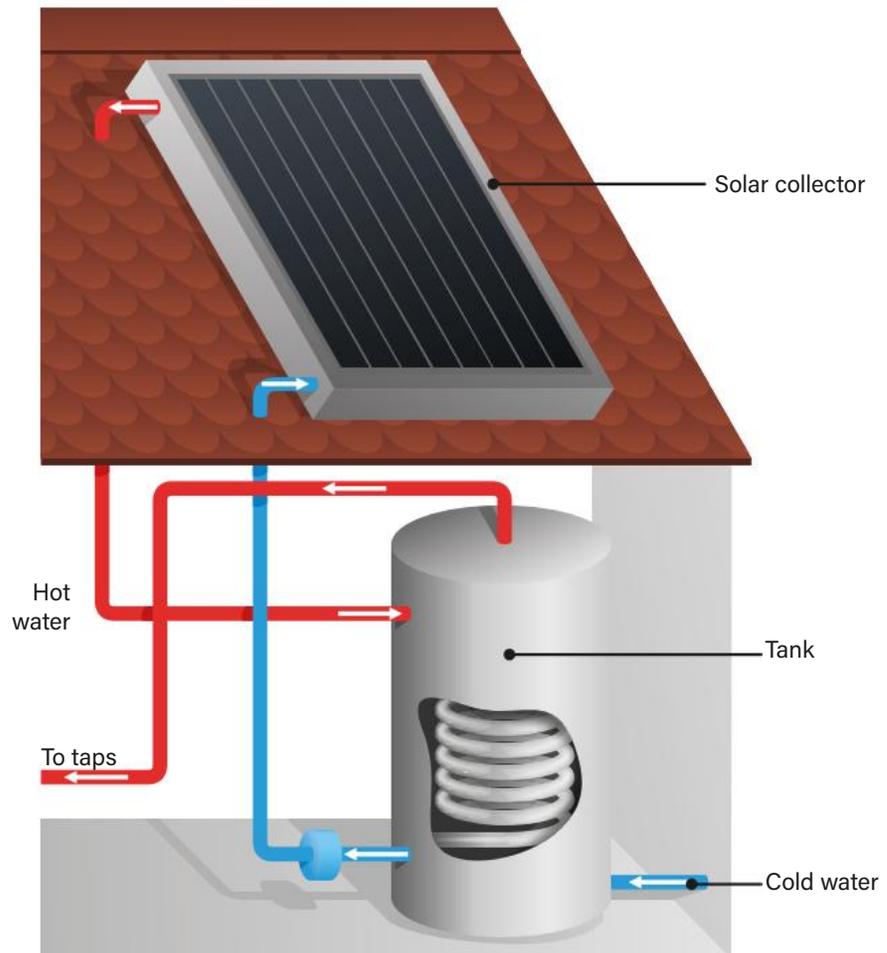


Figure 7.23: In a solar hot-water system, ▶ rooftop solar panels produce hot water for households. Cold water is pumped into the solar collector, which has a glass cover. Solar energy from the Sun enters through the glass and is absorbed by the dark-coloured pipes carrying the water. The water in these pipes heats up and then travels to a storage tank ready for use.

New **heat pump** hot-water systems are becoming popular replacements for gas and electric hot-water systems. A refrigerator pulls heat from inside a box and pumps it out into the surrounding room, making the inside of the box (the fridge) colder. A hot-water heat pump works like a refrigerator in reverse, by pulling heat from the surrounding air and pumping or transferring it into the water storage tank. When the air is too cold to heat the water, there is a back-up electric heater. Heat pumps use 65–70 per cent less electricity than a normal electric hot-water system and reduce **greenhouse gas** emissions.

Figure 7.24: A split-system air conditioner is a heat pump that removes heat from inside the house and pumps it outside. Heat pumps work when a gas in the heat pump expands as it absorbs energy and heats up. When the gas later cools and loses energy, it turns back into a liquid.



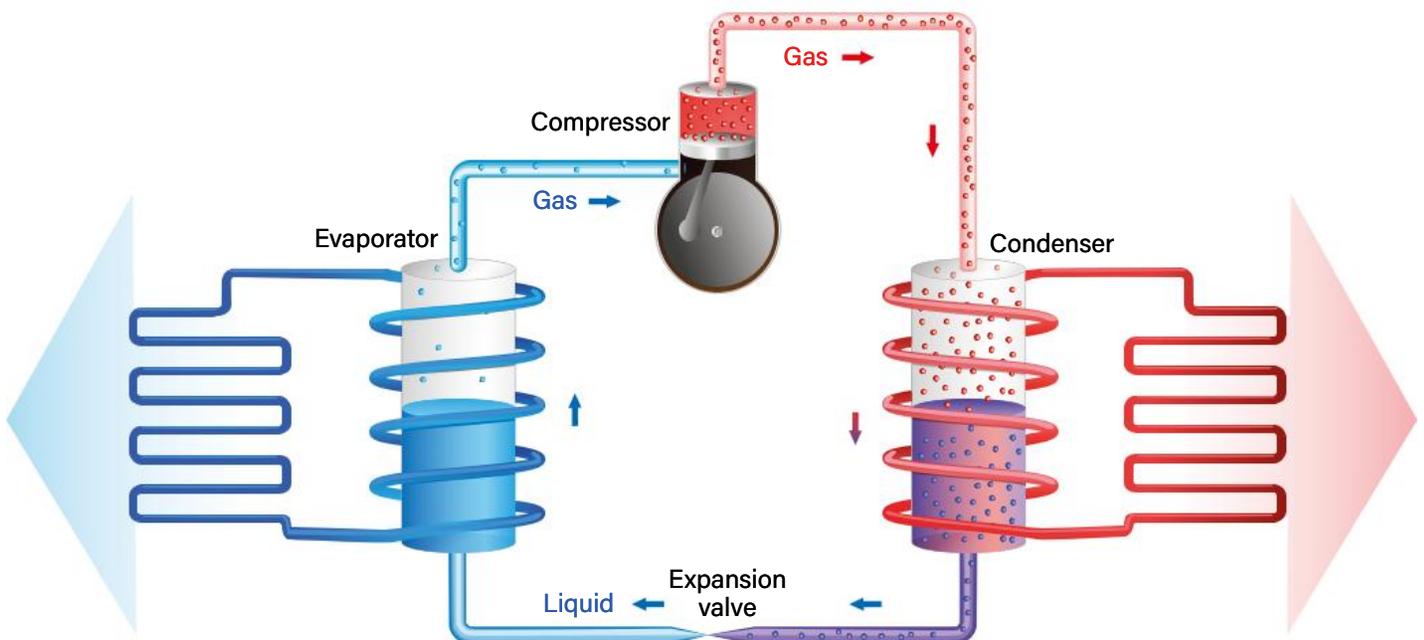
To **optimise** energy use in your house:

- choose energy-efficient appliances
- avoid unnecessary use of appliances
- switch appliances off when not in use
- turn down the temperature on your heater, and turn up the temperature on your air conditioner to the highest level that is comfortable
- install **insulation** or seal up gaps.

Reducing heat energy waste has many advantages

One way to reduce heat loss is by using improved insulation materials. Another way is to stop heat escaping, by blocking gaps such as under doors. We can also recover ‘waste’ heat using heat pumps or steam recyclers. For example, a heat pump, condenser clothes dryer recirculates heat, rather than blowing the hot damp air out and continually adding more heat to dry the clothes.

Reducing heat energy waste saves money and produces fewer emissions and other pollutants. Heat pumps work by a gas in the heat pump expanding when it absorbs heat (Figure 7.24).



Building materials can help to control temperatures

Insulation acts as a barrier to heat transfer. It keeps homes warm in winter and cool in summer. Insulation is rated by a system of R-values. R-values range from 1.5 to 8, with higher R-values being better insulators.

The total R-value of a home is a combination of the R-values of all the materials that make up the walls, floors, roof and ceiling, as well as the insulation used. The best R-value of the insulation used in a home depends on the local climate and the construction of the house.

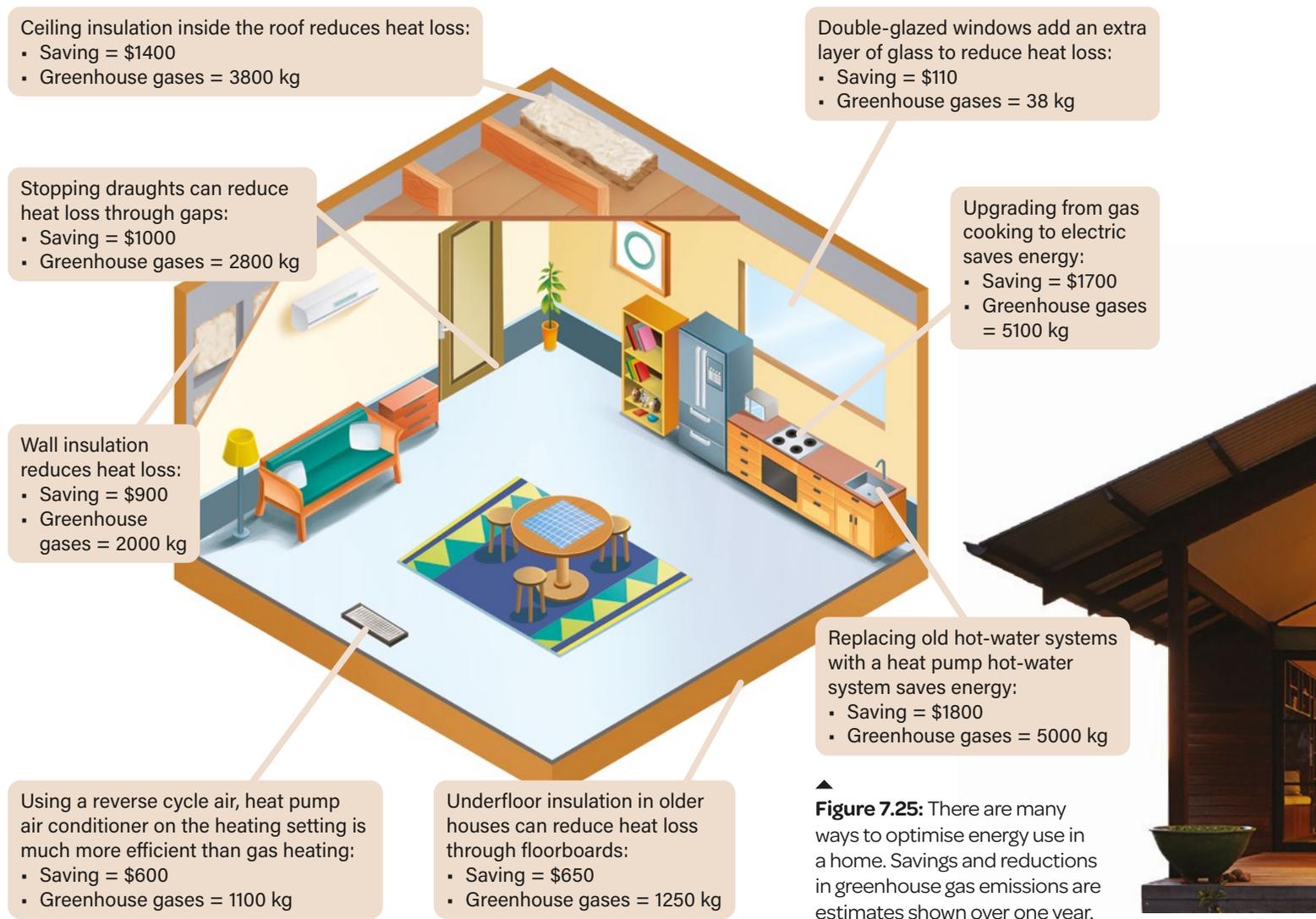
There are two main types of insulation: bulk and reflective. Bulk insulation relies on air trapped in spaces between fibres to reduce the transfer of heat energy, much like wrapping yourself in a blanket to keep warm. Bulk insulation can be made of glass wool, cellulose fibre, polyester, wool or polystyrene.

Reflective insulation has a shiny surface that reflects heat energy away. We will explore insulation further in Section 7.7.

The colour of building materials also affects how much heat energy a building absorbs. Dark, dull surfaces absorb more heat energy than light, shiny surfaces. Light-coloured roofs reflect more heat, keeping a house cooler.

We can optimise energy use in the home

We can save money and reduce greenhouse gas emissions and pollution. We can select energy-efficient appliances and building materials and make good design decisions (Figure 7.25).



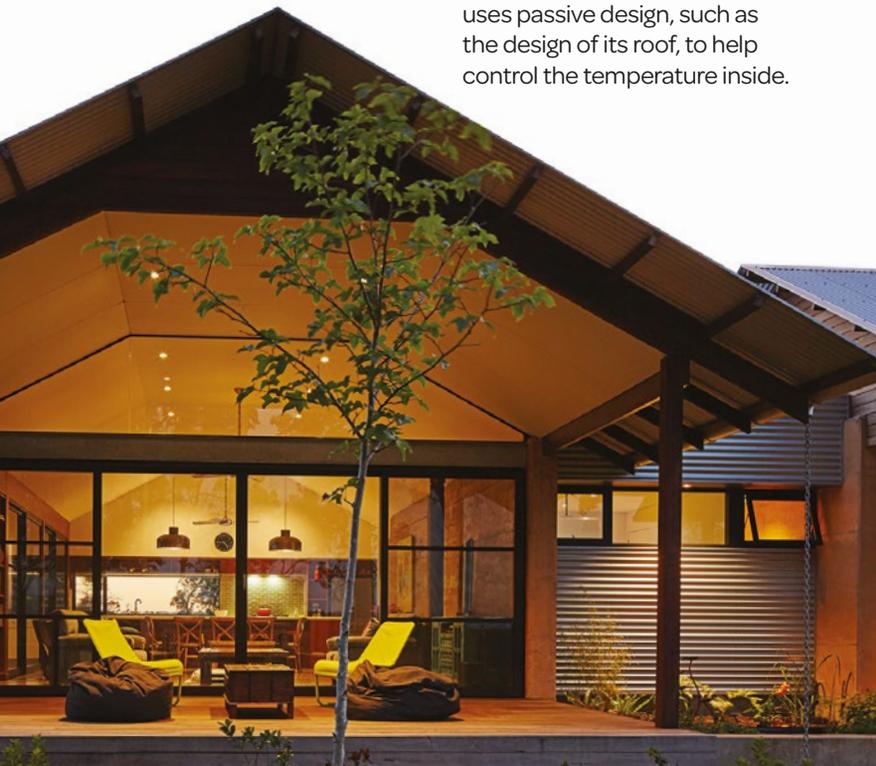
Passive design helps regulate a building's temperature

Passive design is building design that considers the climate, where a building will be located, and design features that will keep it at a comfortable temperature without using appliances for heating or cooling (Figure 7.26). A building made with passive design has features such as:

- windows and doors that are placed to allow air flow that helps to maintain temperature at a comfortable level
- few windows facing the hot afternoon sun, and eaves that shadow the windows in the heat of the day in summer and let sun in during winter
- high and low vents so that cool, fresh air replaces hot, stale air during summer and reduces heat loss during winter
- roof angles and house layout that maximise shade during summer and heat absorption during winter
- building materials that are good insulators, and adding insulation in roof and under floor and walls
- plants that give shade and cool the air, like the canopy in a rainforest.

These features can reduce or eliminate the need for heating and cooling that relies on electricity.

▼ **Figure 7.26:** This Australian house uses passive design, such as the design of its roof, to help control the temperature inside.



Learning Ladder

Energy

- 1 Identify the main forms of energy that are important in understanding energy in the home.
- 2 Using a solar hot-water system as an example:
 - a describe how energy is being transferred and transformed.
 - b outline the difference between energy transfer and energy transformation.
- 3 Draw an annotated flowchart to represent and explain the energy transfers and transformation in a:
 - a solar hot-water system.
 - b heat pump.
- 4 Using data from Figure 7.25 about financial savings and greenhouse gas emission reductions per year:
 - a identify the two best energy optimising changes you could make to a house.
 - b explain why you selected these options.
- 5 Based on the data you collated in Question 4, evaluate whether it is worth spending money to improve the energy efficiency of a home.

Nature and development of science

- 1 Identify one problem with current home design in relation to energy and propose a possible solution.
- 2 In designing a house, propose in relation to energy why it is important to have an architect, a person from council who approves the plans, a builder, and an inspector who checks the final product.
- 3 Explain how new knowledge about energy has led to changes in the construction of buildings over time.

Communicating

p. 255

- 1 Identify and define the six key terms from this section.
- 2 Display the words from Question 1 in a format that shows the relationship between them.
- 3 Construct a government advertisement to help homeowners understand how to save energy.

Key idea: Matter and energy

Conduct research into the energy and cost savings of installing a new heat pump hot-water system or solar electricity system. Calculate how many years it would take to get your investment back and how much energy would be saved over that time.

Success criteria

- I can describe energy transfers and energy transformations involved in the home.
- I can describe how appliance choice and building design can optimise energy efficiency.

7.7 ▶ Insulation and energy



Figure 7.27: Fibre or bulk insulation is installed in the roofs and walls of houses to reduce thermal transfer of heat energy.

Learning intention

At the end of this lesson, I will be able to:

- describe different types of insulation and explain how they increase energy efficiency in regards to energy transfer and energy transformation
- describe different ways that insulation can be used.

Key terms

conductivity: the ability to transfer energy by conduction

double glazing: insulation for windows using two panes or layers of glass

fibre: a thread from animal, plant or human-made material

reflect: to bounce thermal or solar energy off a surface

vacuum: a space that has no matter

Investigation 7.7

Insulation and heat transfer, p. 355

Key idea: Matter and energy

There are many ways to insulate a building. In Section 7.6, we learnt about insulation ratings, or 'R' values, that tell you how effective an insulating material is at reducing heat loss. Insulation is also used in other ways, such as in water bottles or vacuum flasks to keep drinks cold or hot. Insulation acts as a barrier to heat transfer, helping to maintain a more constant temperature.

Fibre insulation traps air

Fibre insulation, also known as bulk insulation, relies on air trapped in spaces between **fibres** to reduce the transfer of heat energy. Clothing and blankets are a form of fibre insulation used to maintain our body temperature. Bulk insulation is made of fibres like fibreglass (or glass wool), cellulose fibre, polyester, wool or foam/polystyrene. As well as reducing thermal energy transfer, such insulation is also effective in reducing the transfer of sound energy.

Shiny insulation reflects heat

Reflective insulation has a shiny surface that **reflects** thermal energy away, preventing it from being absorbed by the material and heating up. It is often made of aluminium foil but can be made of other materials such as stainless steel. Reflective insulation can come in many variations and includes foil wrap and foil batts.

- Shiny *foil wrap* or sheets are flexible and are used to wrap pipes or building frames before the roofing or walls are put in place.
- *Foil batts* have two layers of foil, with either an air space or material such as fibre or polystyrene between the layers to trap air inside them. While the foil on both sides reflects the thermal energy, the layer between them traps air to reduce energy transfer even further. This example combines insulation types to be even more effective.

Reflective insulation cannot reflect 100 per cent of thermal energy. For example, some of the Sun's solar energy will still be transformed into thermal energy.

Double glazing windows reduces heat transfer

Double glazing is a type of insulation for windows, where two panes, or layers of glass, are used instead of a single pane. The gap between the two layers of glass is filled with air (a good insulator), which reduces heat transfer through the layers, making homes stay warm in winter and cool in summer. The surface of the glass also reflects some energy.

The double-glazed window unit is usually sealed so that no air or gas can escape from between the layers. Often argon gas is put between the panes as it is denser than air and conducts less heat, making it an even better insulator than air. Double glazing also reduces the transfer of sound energy.

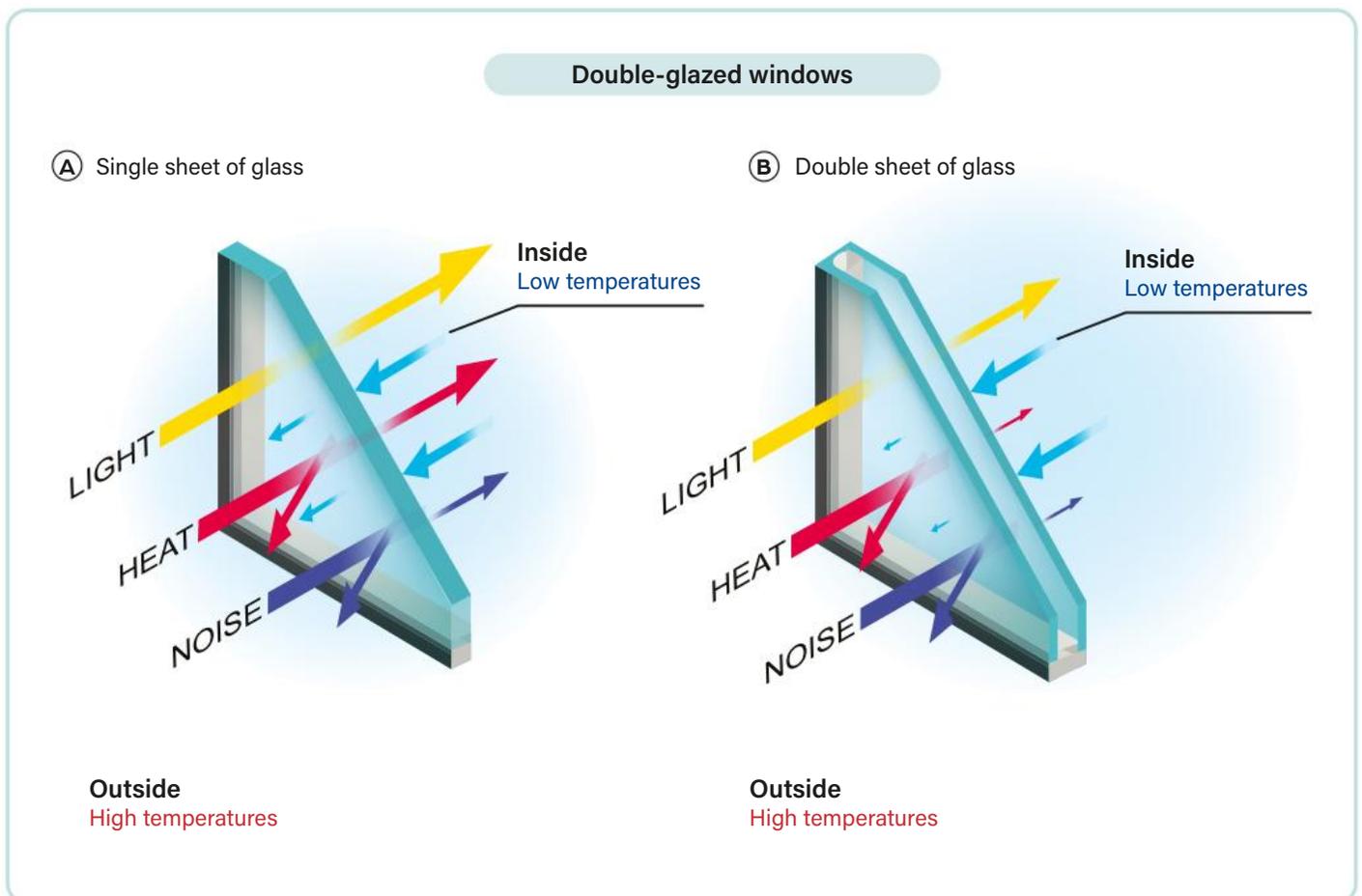


Figure 7.28: Double glazing is an effective insulation technique for reducing thermal transfer in and out of buildings.

Insulation reduces the loss of heat in buildings

A typical building can lose a lot of heat if it is not well insulated. Table 7.3 shows just how much can be lost, and how effective insulation can be.

Table 7.3: Typical heat losses and possible savings through applying insulation

House structure	Typical heat loss (%)	Possible savings in heating or cooling energy if insulated (%)
Windows and doors	20	5
Walls	15–20	25
Floor	10–20	20
Roof	25–35	45

Figure 7.29: Bubble wrap is used as insulation, including in pool covers. By trapping air in the bubbles, it reduces thermal transfer.



A vacuum can reduce heat transfer

A vacuum flask, or Dewar flask, is a bottle that can help to maintain the temperature of the liquid stored inside. The first vacuum flask was invented by a Scottish scientist, Sir James Dewar, in the early 1890s to keep his laboratory chemicals cold. He could not have predicted that his invention would still be used today!

A vacuum flask reduces the thermal transfer of heat energy in a number of ways.

- The double-layered glass wall is coated on each side with a shiny surface to help reflect heat.
- The two layers of glass create a **vacuum** between them – that is, a space with no air or other matter. The vacuum reduces thermal **conductivity** and heat transfer.
- A protective layer of plastic or steel is wrapped around the outside of the flask.

Modern flasks or water bottles may use stainless steel rather than glass and only have two layers as, without glass, a third protective layer is not needed.

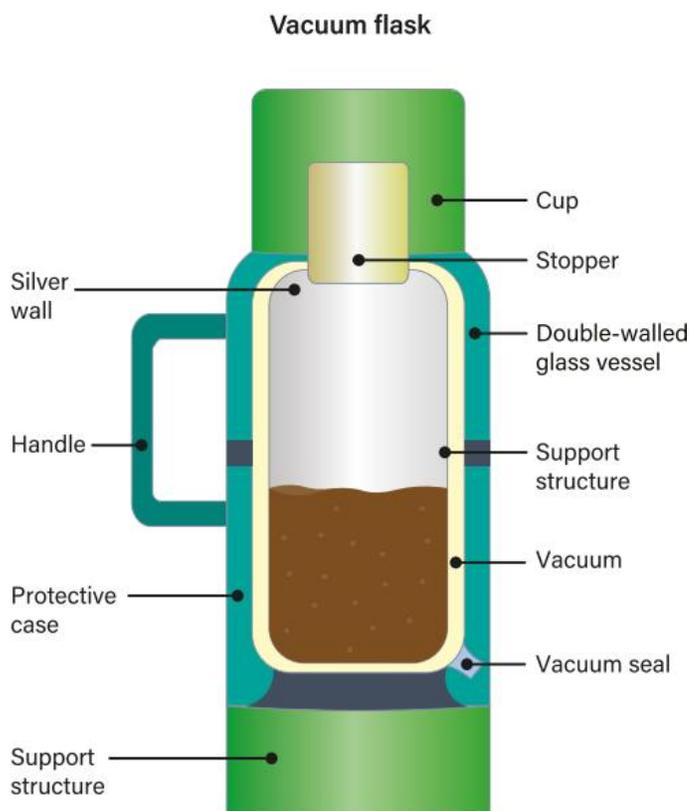


Figure 7.30: A vacuum can reduce the transfer of thermal energy, as shown in this vacuum flask design.

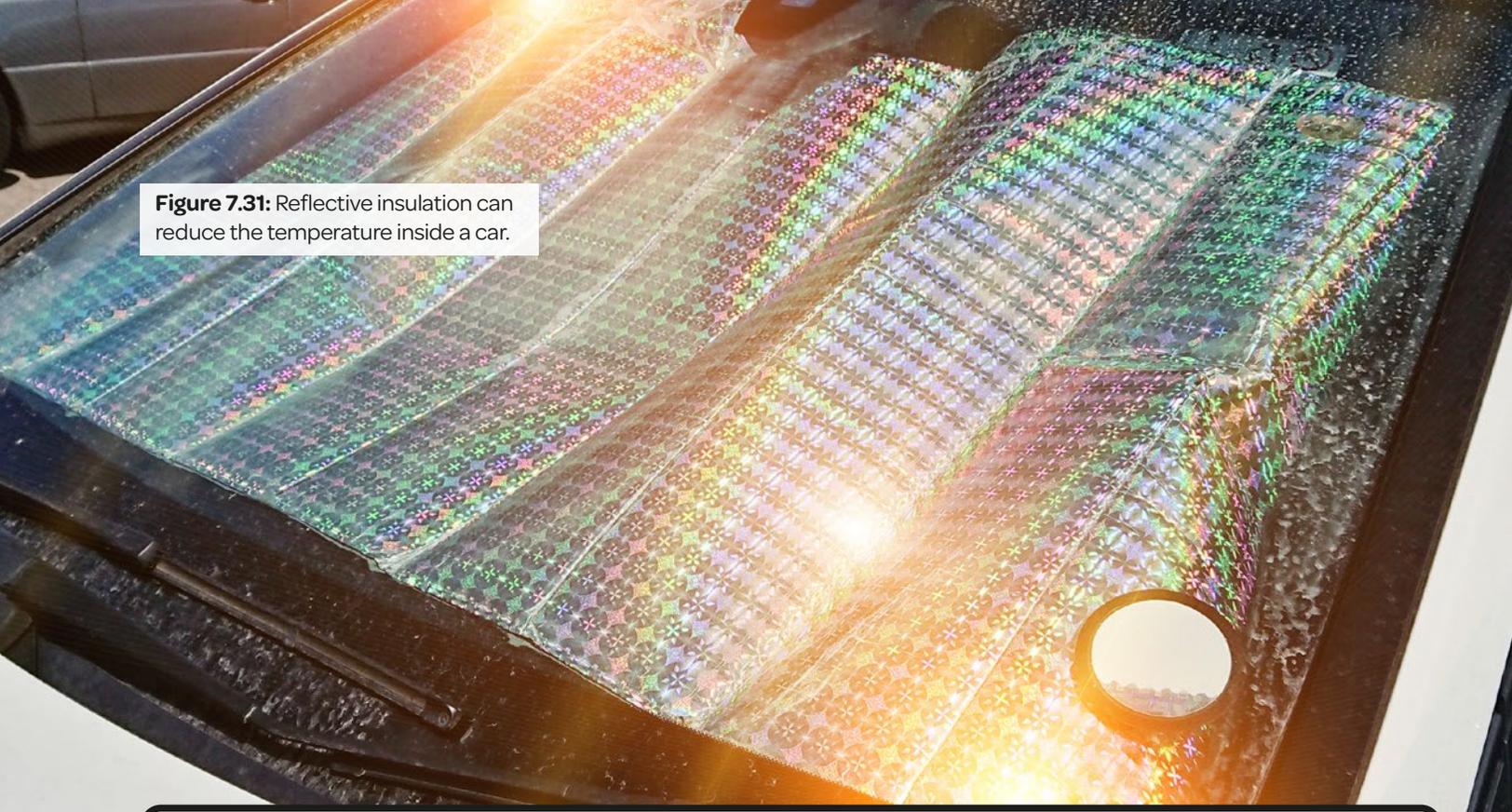


Figure 7.31: Reflective insulation can reduce the temperature inside a car.

Learning Ladder

Energy

- 1 Identify two types of energy whose transfer can be reduced by insulation.
- 2 Identify and describe an energy transfer and an energy transformation using an example of a type of insulation.
- 3 Construct a diagram of a vacuum flask showing all the layers. Use arrows to represent the flow of thermal energy as a flask containing hot water cools very slowly over time. The size of your arrows should represent the amount of energy, as you saw done in Figure 7.28.

Use and influence of science

- 1 Identify one positive or one negative aspect of using insulation.
- 2 Describe how our understanding of insulation has affected the way buildings are now constructed.
- 3 Give an example of how the increased use of insulation has had economic impacts for homeowners.
- 4 Discuss how our understanding of insulation may reduce our impact on the environment.
- 5 Analyse why it is important for the government to set regulations and policies for the use of insulation in new buildings.

Processing, modelling and analysing

p. 240

- 1 Review the second column of Table 7.3. Identify which house structure, when insulated, best reduces heat loss.
- 2 Rearrange Table 7.3, ordering the structure from the most to least effective structure to insulate.
- 3 Construct a bar graph (or graphs) of the data in Table 7.3, in a format that makes it easier for people to understand which insulation method is most effective.
- 4 Discuss the data in Table 7.3 and propose reasons why the amount of heat lost does not always match the possible heat savings shown.
- 5 In Table 7.3, there is one piece of data that seems different from the others. Identify and describe this anomaly.

Key idea: Matter and energy

Research building regulations in your area in regard to the requirements for insulation in a new home. Produce a flyer for people who are planning to build a home that explains how insulation reduces energy transfer and the regulations they must follow in designing their new home.

Success criteria

- I can describe different types of insulation and how they increase energy efficiency.
- I can describe different ways that insulation can be used to reduce energy transfer and increase efficiency.

7.8 ▶ Key idea: Matter and energy – home energy audit

Learning intention

At the end of this lesson, I will be able to undertake an energy audit to analyse household energy consumption and efficiency.

Key terms

audit: an investigation carried out in order to form an opinion based on a set of principles or guidelines

consumption: use of a resource, such as energy

Investigation 7.8

Household energy audit, p. 357

Key idea: Matter and energy

Figure 7.32: How you use energy in the home is impacted by the appliances you use, the design of your house and human behaviour (the way you behave). Home automation can also help to control energy usage.



Figure 7.33: Energy use in a typical Australian home

- Lighting
- Hot water
- Heating and cooling
- Refrigerator
- Kitchen appliances and cooking
- Laundry
- Lifestyle and other appliances



Energy plays a key role in how we live our lives.

Our homes are comfortable because we control and use energy to make our environment suit our needs.

For example, we set the temperature at levels we want, even as it gets hot or cold outside. To be more energy efficient, and to reduce waste, we need to understand our home energy use, including how we use and conserve energy. So, let's get started!

How much energy do households use?

In Australia, households use about 11 per cent of the nation's total energy, but that figure has been dropping slowly over the past 20 years. This is mainly due to the increase in energy-efficient appliances, including water heaters, heating and cooling, and lighting. Building design is also improving, and government programs to decrease energy loss from old houses are helping. Figure 7.33 shows the typical breakdown of how energy is used in the home. The actual energy used in each household will vary depending on the size of the house, the location in Australia and the habits of the people living there.

An audit helps us to understand our energy use

An **audit** is an investigation to collect data and information using a set of criteria. In this case, the audit of your home will examine:

- energy **consumption** or use
- the efficiency of your appliances
- your building's design, including where energy is wasted and whether your home is designed to be efficient
- the behaviours of people in your home that may impact the use of energy
- your energy bills, to see if your home is efficient compared to others.

As you conduct your audit, you will collect a number of pieces of data and other information and use a checklist to assess your current energy consumption, efficiency and waste. This information will allow you to assess how efficient your home is. Using the information collected, you will be able to identify issues and propose ways to make improvements to your energy consumption and efficiency and to reduce energy waste.

Energy consumption and waste is affected by behaviours

As well as appliance or building design, people also impact how we use energy! Choices you make about whether to turn off the lights when you leave a room, to turn down the heating and put on a jumper, and to turn off the heater when you go to school can all affect the amount of energy required, or wasted. Your home energy audit will not just look at the physical appliances and structures in your home but will also investigate behaviours that can make a difference.

Energy bills can compare if your home is efficient

As part of your audit, you will review an energy bill from your home. We have learnt to calculate the cost of running an appliance, using kilowatt hours of energy consumed and the tariff (cost per kilowatt hour) to find the total cost over time. An energy bill uses the same method to work out how much you need to pay. Most bills also show a comparison to similar households based on the number of people who live there, like the one in Figure 7.34. During your audit, you will look at your bills and think about how your energy use compares to others' use.

You will undertake your household energy audit by completing Investigation 7.8.

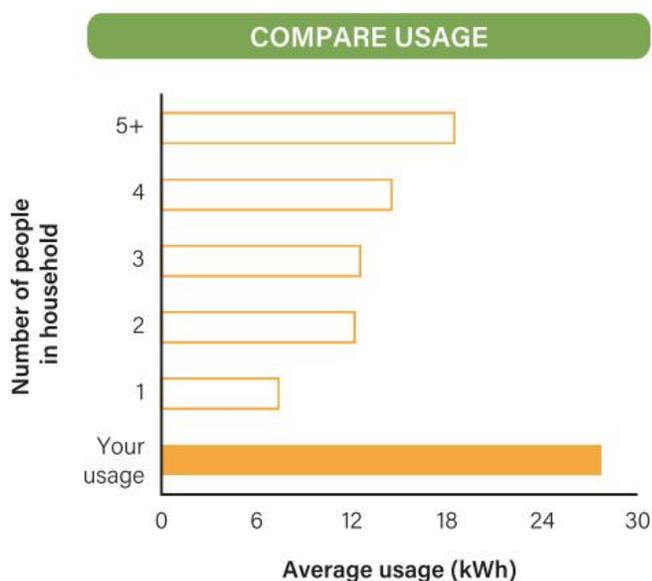


Figure 7.34: A typical electricity bill will compare your energy use to other households' use. This household has six people.

Learning Ladder

Energy

- 1 Identify forms of energy you could investigate in a home energy audit.
- 2 Describe an energy transfer and a transformation you may see during your audit.
- 3 Select a category shown in Figure 7.33 and construct a diagram showing the forms of energy going in, and the energy transfers and transformations that occur as the energy is used.
- 4 From Figure 7.33, identify the top two areas of energy use in your home. Describe changes of behaviour that could reduce energy consumption.
- 5 Propose two ways you might decrease energy consumption and wasteful energy use in your home.

Use and influence of science

- 1 Review Figure 7.33 and identify a social issue that is relevant to this data.
- 2 The graph in Figure 7.34 comes from an energy bill. Describe how sharing scientific knowledge about energy use may help people to save energy.

Processing, modelling and analysing p. 240

- 1 Review Figure 7.34, which compares energy use in households per day. The household shown by 'Your usage' has six people. Identify whether their energy use is more efficient or less efficient than average.
- 2 Using Figure 7.34, construct a table that includes the amount of energy in kilowatt hours that each household of a different size typically uses per day.
- 3 **a** Calculate how many more kilowatt hours the six-person household used than the most similar-sized household.
b If the tariff is 19 cents per kWh, for the six-person household calculate the cost of electricity:
 - i per day.
 - ii per month.

Success criteria

- I can undertake an energy audit to analyse household energy consumption and efficiency.
- I can explain how energy consumption is affected by appliance choice, building design, climate and behaviour.

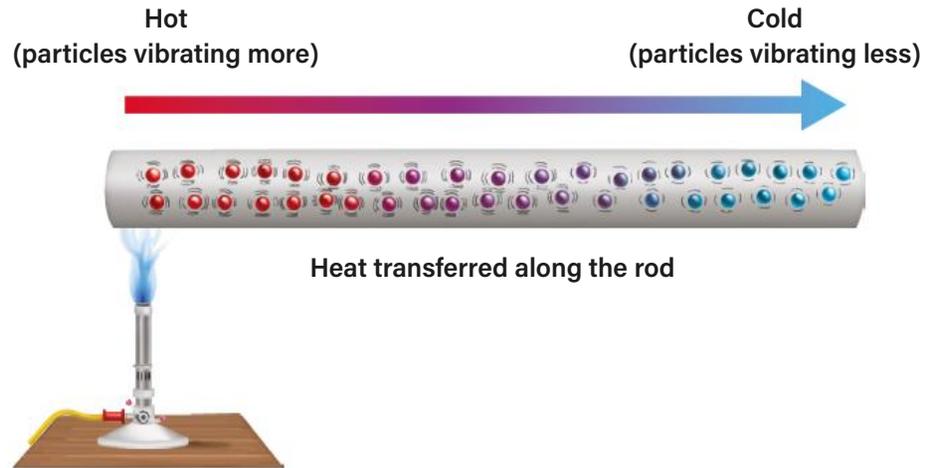
► Summary

Energy comes in different types and can be classified as kinetic or potential.

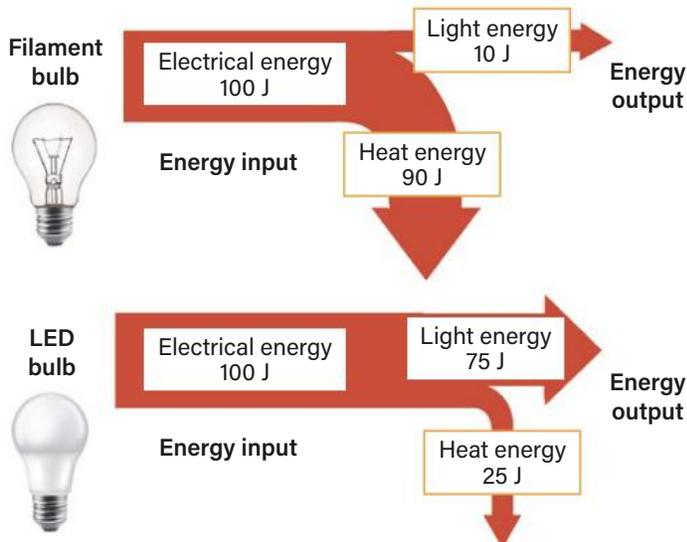
Energy type	
Kinetic	Motion
	Thermal
	Light
	Sound
	Electrical
Potential	Gravitational
	Elastic
	Chemical
	Nuclear

Energy can be transferred by:

- conduction: the transfer of energy through a substance
- convection: the transfer of energy by movement of a liquid or gas
- radiation: the transfer of energy that does not require contact with matter.



- Energy is measured in joules (J).
- A system is when several simple things work together to perform a function.
- Energy transfers and energy transformations cause change in systems.
- Efficiency is a measure of how much useful energy is transferred or transformed during a change.
- An efficient device will have a high amount of useful energy and little waste. An inefficient device will have a low amount of useful energy and a high amount of energy wasted.



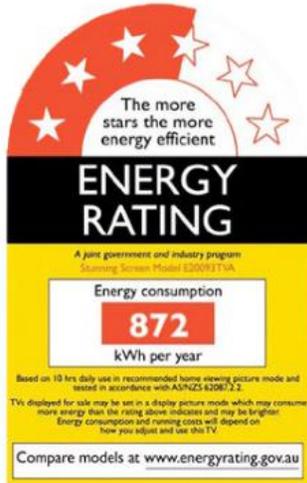
First Nations Peoples use friction to start fire by four methods:

- fire drill
- fire saw
- fire plough
- percussion.

The friction creates a small burning ember or a spark. This is placed into a tinder bundle to start the fire.



- Energy-efficient appliances are cheaper to run and are better for the environment.
- Star ratings allow you to compare products – the more stars, the more efficient an appliance is.

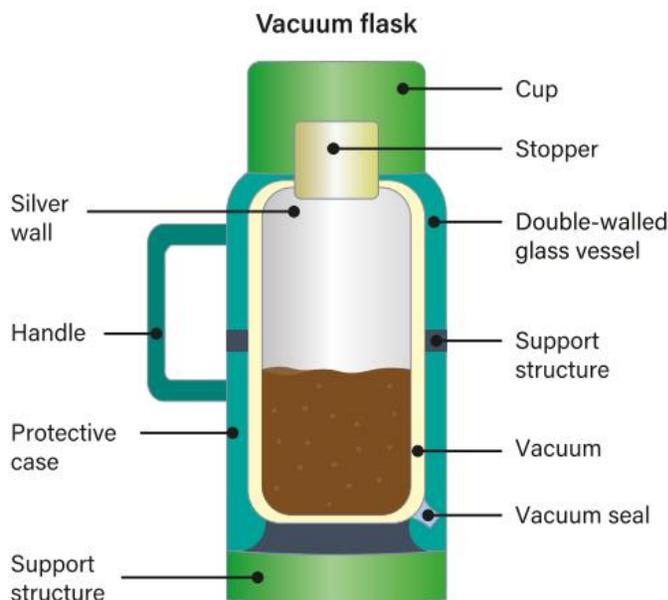


- Optimising energy use reduces waste and the cost of running a household.
 - Energy sources should be used efficiently.
 - Insulation reduces heat transfer and loss, such as through floors and ceilings.
 - Insulation is rated by R-values from 1.5 to 8. Higher R-values are better insulators.
- Passive design helps to regulate a building's temperature. It considers:
 - where a building will be located
 - design features that will keep it at a comfortable temperature
 - the location and type of windows and doors.



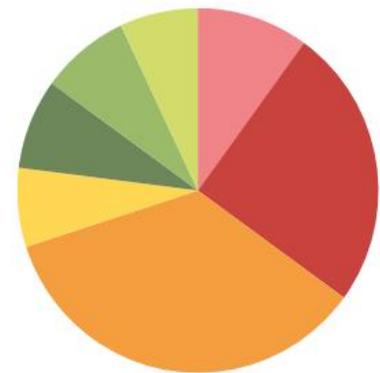
Insulation acts as a barrier to heat transfer, helping to maintain a more constant temperature.

- Bulk insulation traps air in fibres to reduce heat transfer.
- Reflective insulation reflects thermal energy away.
- Double glazing traps air between layers of glass to reduce thermal transfer.
- A vacuum reduces thermal transfer by creating a barrier with no air.



Key idea: Matter and energy

A **home energy audit** is used to understand how energy is used and wasted and how to improve efficiency in the home.



- Lighting
- Hot water
- Heating and cooling
- Refrigerator
- Kitchen appliances and cooking
- Laundry
- Lifestyle and other appliances

Masterclass

Steps in progression

1

2

Science understanding	Energy	Identify and classify the forms of energy that are involved in Figure 7.35.	Outline an energy transfer and an energy transformation in Figure 7.35.
	Nature and development of science	Propose a problem related to the disposal of batteries.	When developing new batteries, describe why it is important for different areas of science to collaborate.
Science as a human endeavour	Use and influence of science	Outline an economic issue related to rechargeable batteries.	Describe how our knowledge of chemistry and the creation of portable energy supply has affected society.
	Processing, modelling and analysing	Identify the most efficient battery type from Figure 7.36.	Display the data from Figure 7.36 in a table that ranks the batteries from least to most efficient.
Science inquiry	Communicating	Identify and define five important terms related to batteries and energy efficiency.	Describe an appropriate format of communication to explain battery efficiency to people buying a new battery.

Figure 7.35: Charging a satellite phone and head torch is possible with this solar-powered portable power bank.



Batteries and energy

There are many ways to generate electricity, all of which involve energy transfer and energy transformation. Batteries are devices that store energy as chemical potential energy. Through a chemical reaction, the chemical energy is turned into electrical energy that can be used to power a device.

There are many different types, shapes and sizes of batteries. These may include acid batteries, alkaline batteries and lithium-ion batteries. The properties of batteries, such as how long they last, how much energy they can produce, how they can be used and whether they can be recharged, depend upon the chemicals used inside them. Figure 7.35 shows a power bank (with solar panels and battery inside) being used to recharge a satellite phone and a torch. Portability is one of the benefits of small batteries, allowing you to take power with you as you travel.

Demonstrate your understanding

3

4

5

Using Figure 7.35, construct a flowchart showing the energy transfers and energy transformations from the Sun's energy to when light is created by the torch.	If none of the batteries in Figure 7.35 are 100 per cent efficient, explain where the lost energy goes.	Evaluate how solar cells and batteries when used together can decrease energy consumption or waste.	
Explain how new evidence may have led to the development of new batteries that are more efficient.	Propose and discuss how our increasing knowledge of solar energy has contributed to the development of solar cells for recharging batteries.	Analyse why some people may not want portable batteries and energy sources when going off-grid camping.	
Explain an example of environmental impacts from the development of batteries.	Discuss how the development and increased use of mobile phones has increased the need for portable power banks to recharge on the go.	Analyse how the increased use of batteries has led to regulation in regard to the disposal and recycling of batteries.	
If a battery during charging uses 250 watts of energy and produces 220 watts of usable energy, calculate the round-trip efficiency.	Discuss your observations of efficiency and any trends in the data about batteries shown in Figure 7.36.	Analyse the graph in Figure 7.36 and explain whether there is a difference between rechargeable and non-rechargeable batteries.	Science how-to p. 240
Construct a diagram to communicate the concept of round-trip efficiency.	Construct a video that communicates important facts about batteries and energy efficiency in an engaging way.	Create a scientific argument about why non-rechargeable batteries should be banned.	Science how-to p. 255

Some batteries are also more efficient than others, as shown in Figure 7.36. Efficiency is measured by looking at how much energy is put in when charging a battery, compared to how much useful energy comes out. For example, if 100 watts of energy is put into a battery, and only 80 watts of energy is usable, then the efficiency would be 80 per cent. This measure of efficiency in batteries is called the round-trip efficiency, as it measures the efficiency of the charge-and-discharge cycle.

$$\text{Round-trip efficiency} = \frac{\text{Usable energy}}{\text{Energy input}}$$

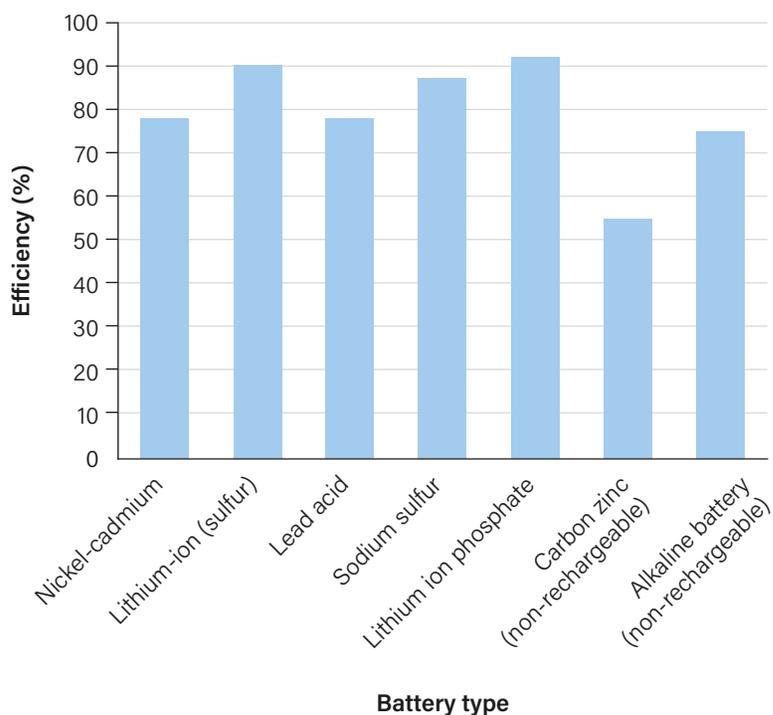


Figure 7.36: The energy efficiency of some different types of batteries

8.0 Electricity

What would we do without electricity? Imagine no lights at night, no heating, no mobile phones! Electricity is a form of energy that can flow from one place to another. It is the flow or movement of electrons, which may occur in an electric circuit through wires. But electrons can also move through the atmosphere as lightning! Electricity also occurs in our body and may even 'zap' us on the trampoline or when we pull a jumper over our head and see sparks. Famous scientists including Thomas Edison, Nikola Tesla and Albert Einstein all created inventions that help us use electricity in our world today. These inventions contained electrical circuits, and things like light bulbs and speakers that you will learn more about in this chapter.



Learning Ladder

The Learning Ladder for each chapter maps the Science Understanding, Science as a Human Endeavour and Science Inquiry strands that will be covered. Each ladder has five levels of progression, called steps. To climb the ladders, you need to develop fluency at each step. This will help you develop the ability to complete tasks that are more complex.

Steps in progression	5	I can analyse a variety of electrical circuits and their components, designed for diverse purposes	I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations
	4	I can observe and make predictions about voltage, current and energy transfer in circuits	I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues
	3	I can design and construct series and parallel circuits	I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances
	2	I can describe how circuits operate, with reference to voltage and current	I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society
	1	I can recognise that a circuit demonstrates energy transfer	I can recognise scientific problems and solutions	I can identify socio-scientific issues
		Physical science: Electricity	Nature and development of science	Use and influence of science
		Science understanding	Science as a human endeavour	



Figure 8.1: Lightning is a display of electricity, as electrons jump from the clouds to Earth.

I can evaluate investigation questions and predictions for scientific validity	I can evaluate conclusions and claims with reference to conflicting evidence and unanswered questions	5
I can develop a hypothesis that predicts the relationship between investigation variables	I can create evidence-based arguments to justify conclusions or evaluate claims	4
I can construct questions and predictions to investigate scientific problems	I can use science-based explanations to support investigation findings	3
I can make simple predictions based on what I know and observe	I can describe different types of errors in an investigation method	2
I can recognise questions that can be investigated scientifically	I can identify errors and assumptions in an investigation	1
Questioning and predicting	Evaluating	Steps in progression
Science inquiry		

8.1 ▶ Introduction to fields

Learning intention

At the end of this lesson, I will be able to explain fields in terms of forces and outline how forces, electricity and magnetism are connected.

Key terms

attractive force: a force that pulls objects towards each other

electric field: an area around a charged particle in which it exerts a force on other charged particles

electricity: the movement of charged particles

electromagnet: a magnetic field produced by electricity

electrostatic force: an indirect force between any objects with an electric charge

field line: a line used to show the direction of a force within a field

magnetic field: an area around a magnet in which it exerts a force on other objects

magnetic force: an indirect force that affects any object made of certain metals

radial field: a field in which the field lines radiate from a centre

repulsive force: a force that pushes objects away from each other

Investigation 8.1

Magnetic shielding, p. 361

Key idea: Scale and measurement

Indirect forces act through fields. In a field, objects do not need to touch each other to be affected by the force. Magnetic fields occur around magnets and are used in generating **electricity**. Electric fields occur around charged particles. If you understand fields, you can learn more about electricity.

Indirect forces produce a field around objects

Indirect forces can work at a distance, without contact, as long as objects are in their fields.

- **Magnetic forces** affect objects made of certain metals, such as iron, nickel or cobalt, that have magnetic properties.
- **Electrostatic forces** affect objects that have an electrical charge, even very weak charges.
- **Field lines** show the direction in which forces act in a **magnetic field**.
- It can be hard to estimate where a field ends, as they normally get weaker the further they are from an object.
- Objects can block or shield some fields.

Magnetic fields form around magnets

If you sprinkle iron filings near a bar magnet, most of them arrange themselves at the ends of the magnet (see Figure 8.2a). This shows that the strength of the magnetic force is not the same throughout the field.

Figure 8.2b shows the magnetic field lines around the bar magnet. The field is strongest where the field lines are closer together, at the ends of the magnet. You can see that the field lines match the pattern of iron filings in part a of the figure.

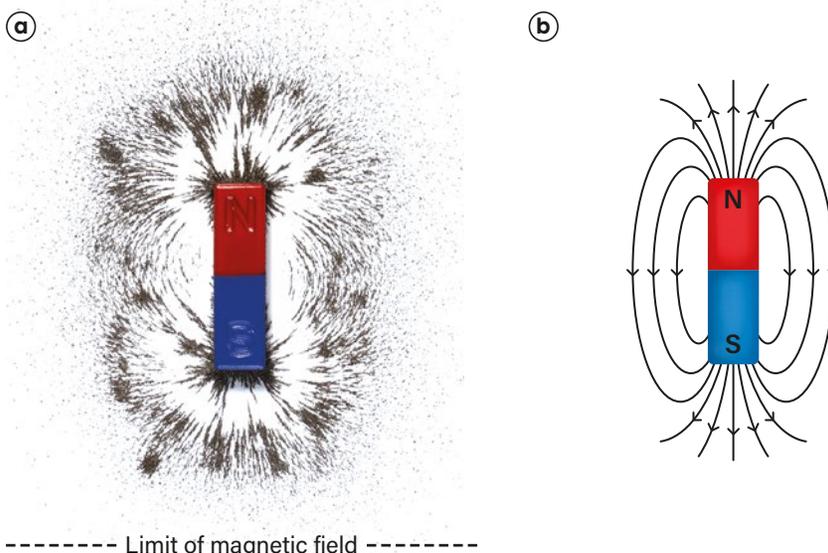


Figure 8.2: (a) Iron filings gather in the areas around a magnet where the magnetic field is strongest. Beyond the limits of the field, the filings are no longer attracted. (b) Field lines show how the different non-contact forces operate within the magnetic field.

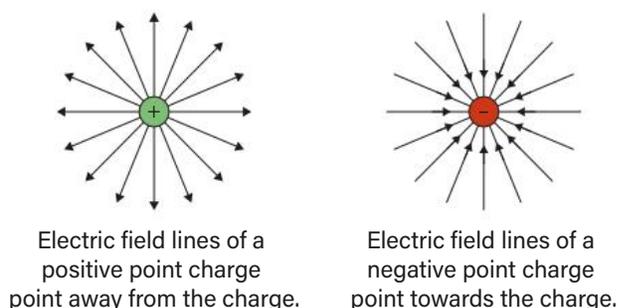
Electric fields form around charged objects

An **electric field** exists around a charged object. The electric field radiates outwards from a positive charge and inwards towards a negative point charge, as shown in Figure 8.3.

Charged particles have a **radial field**. However, the electrostatic force within the electric field can be **attractive** (pulling) or **repulsive** (pushing), depending on the charged object. This means that charges produce a force in the field area that can either attract or repel other charges.

The charged objects can be different types of particles, including a proton or an electron. A neutron has no charge (is neutral) and therefore does not have a field around it.

Figure 8.3: Electric fields of individual charged particles (point charges)

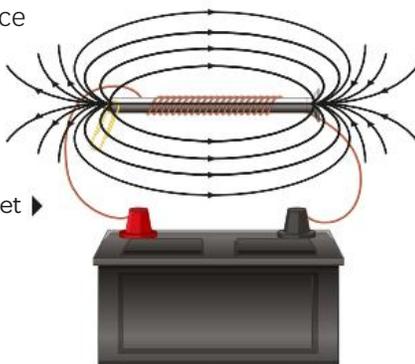


Electricity and magnets can work together

Electric fields and magnetic fields have a close relationship. Changing a magnetic field can produce electricity, because a magnetic field causes electric charges to move. And the opposite can occur: moving electric charges can create a magnetic field. This is often why scientists talk about electromagnetic fields.

For example, we can make a simple **electromagnet** using electricity (moving charged particles) to make a magnetic field. Figure 8.4 shows an electromagnet made of a coil of wire wrapped around a nail and connected to a battery. The battery causes the charged particles to move inside the coil of wire. The moving charged particles in the coil of wire produce a magnetic field, with field lines just like a magnet.

Figure 8.4: An electromagnet uses electricity to make a magnetic field.



Learning Ladder

Electricity

- 1 Identify:
 - a the direction of the field around a positive particle.
 - b the direction of field around a negative particle.
 - c the type of object an electrostatic force may affect.
- 2 Describe:
 - a what electricity is.
 - b the difference between an electric field and a magnetic field.
 - c how an electromagnet is made.

Nature and development of science

- 1 A scientist wanted to produce a giant magnet that could turn off and on so that it could pick up, move and drop old cars at the scrapyards. Propose a solution to this problem.
- 2 Describe the importance of scientists working together to create new inventions that use fields.
- 3 Use an example from this section to explain how our understanding of electric fields and magnetic fields has led to new scientific knowledge.

Questioning and predicting

p. 232

- 1 Identify a question about fields that you could investigate further.
- 2 Study Figure 8.3. Predict what may happen if a positively charged particle and a negatively charged particle come into each other's field. Explain your answer.
- 3 A scientist wanted to increase the force of the magnetic field from the electromagnet in Figure 8.4. Construct a scientific question to investigate this problem.
- 4 For the investigation in Question 3, construct a hypothesis that predicts the relationship between variables.
- 5 Evaluate the scientific question you wrote in Question 3. Suggest whether it would lead to a valid question to investigate.

Key idea: Scale and measurement

Design and construct a diagram of an invention that uses a field (an indirect force without contact) to measure something useful. For example, could you use a magnet to make a measuring device?

Success criteria

- I can explain fields in terms of indirect forces.
- I can outline how forces, magnetism and electricity are connected.

8.2 ▶ Electrostatic forces

Learning intention

At the end of this lesson, I will be able to explain, in relation to particle theory, why objects have a charge and identify when they will exert a force on other objects.

Key terms

electron: a subatomic particle that orbits the nucleus of an atom; it is negatively charged

electrostatic charge: the electric charge on the surface of an object

neutron: a subatomic particle located in the nucleus of an atom; it is neutrally charged

nucleus: the centre of an atom, which contains protons and neutrons

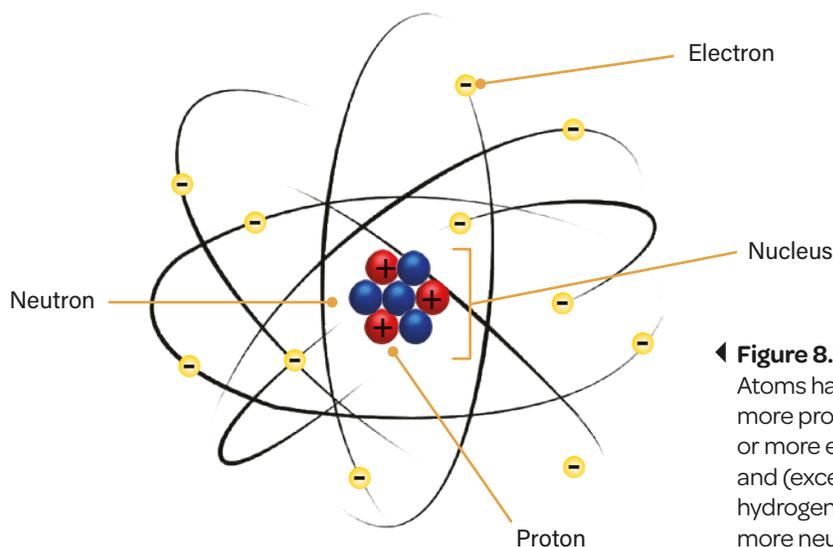
proton: a subatomic particle located in the nucleus of an atom; it is positively charged

Investigation 8.2

Charging balloons, p. 362

Key idea: Scale and measurement

All matter is made up of atoms. At the centre of each atom is the **nucleus**. The nucleus is made up of uncharged particles called **neutrons** and positive particles called **protons**. Around the nucleus are one or more negative particles called **electrons**.



◀ **Figure 8.5:** Atoms have one or more protons, one or more electrons, and (except for hydrogen) one or more neutrons.

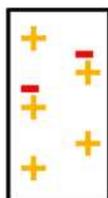
Charged objects can have a positive or negative charge

Each proton and electron carries a tiny electric charge. The positive charge of a proton is equal but opposite to the negative charge of an electron. When the number of protons is the same as the number of electrons, the atom has no overall charge: it is neutral.

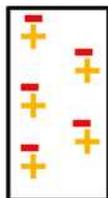
When an atom has more protons than electrons, it has a positive charge. When it has more electrons than protons, the atom has a negative charge. This gives an object an overall **electrostatic charge** and it can exert an electrostatic force on other objects, whether they are charged or uncharged (see Figure 8.6).

Like charges repel; opposite charges attract

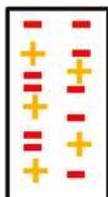
When two objects with the same charge (positive or negative) are brought close together, they experience a repulsive force that pushes them apart. When two objects with opposite charges are brought close together, they experience an attractive force that pulls them even closer together. You can see this in the balloons in Figures 8.8–8.10. Balloons can be given an electrostatic charge by rubbing them with wool or rubber. Charged balloons will attract or repel other charged balloons that are close enough to be in their electrostatic field.



Positively charged = more protons than electrons



Neutral = same number of electrons and protons



Negatively charged = more electrons than protons

▲ **Figure 8.6:** If an object has different numbers of protons and electrons, it has a positive or negative electrostatic charge.



Figure 8.7: A Van de Graaff generator is a device that creates a build-up of electric charge. Here it has transferred electrons to the woman. Each strand of her hair has the same charge, so they repel each other. This is why her hair is standing on end.

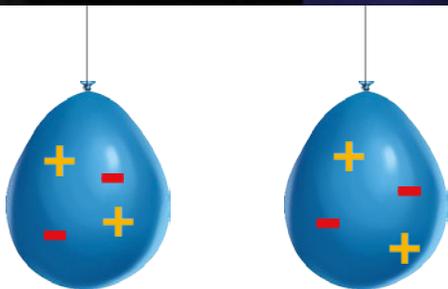


Figure 8.8: Two balloons with neutral charge hanging close together will not attract or repel each other, so they hang straight down.

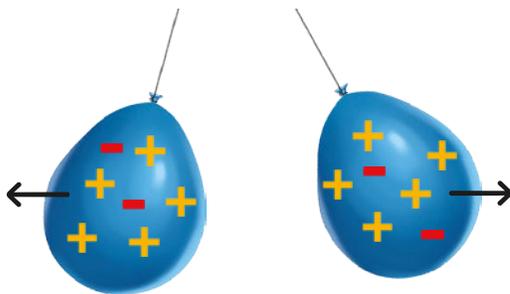


Figure 8.9: Two balloons close together and with the same charge repel each other, so they push away from each other. This is because they experience an electrostatic force. If the charged balloons are moved further apart, and are outside each other's electrostatic field, then they will not experience a force.

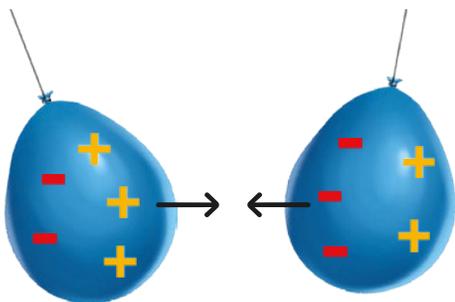


Figure 8.10: Two balloons close together and with opposite charges attract each other. The attractive forces pull them slightly together.

Learning Ladder

Electricity

- 1 Identify:
 - a the three particles that are found inside an atom.
 - b the types of charges an object can have.
- 2 Describe:
 - a the difference between a positive, negative and neutrally charged object.
 - b when charged objects will attract or repel.
 - c how a Van de Graaff generator makes your hair stand on end.
- 3 Construct a diagram of two balloons next to each other, one neutral and one positive.
- 4 Refer to your diagram from Question 3.
 - a Predict whether the electrostatic forces of the charged balloon will interact with a neutral object.
 - b If you answered 'yes' to part a, indicate whether the balloons will attract or repel.
- 5 Propose how a charged object can be made neutral.

Use and influence of science

- 1 Identify a situation where you have experienced an annoying electrostatic force.
- 2 Describe an example of when electrostatic forces could be useful.
- 3 Electrostatic forces are used in many inventions, including photocopiers and printers. Explain how these scientific advances have impacted society.

Evaluating

p. 249

Read Investigation 8.2 and answer the following questions.

- 1 Identify which of the following statements is more likely to be an assumption made in this investigation:
 - A Hair is not able to be electrically charged.
 - B Charges can move between objects when they are rubbed together.
- 2 Identify and describe an error that may occur when completing this investigation.

Key idea: Scale and measurement

Static shocks happen every day in small-scale systems that produce small amounts of electricity. Describe when you have felt static shocks. What materials were interacting to create a charge?

Success criteria

- I can identify charged or neutral objects.
- I can explain why objects have a charge.
- I can describe when the electrostatic forces of charged or neutral objects will interact with each other.

8.3 ► How charged particles behave

Learning intention

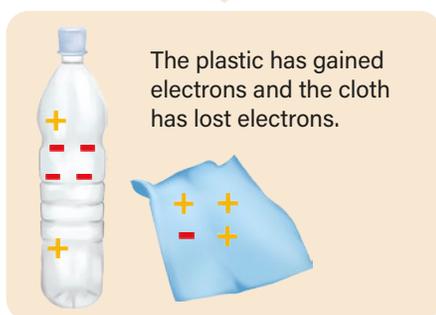
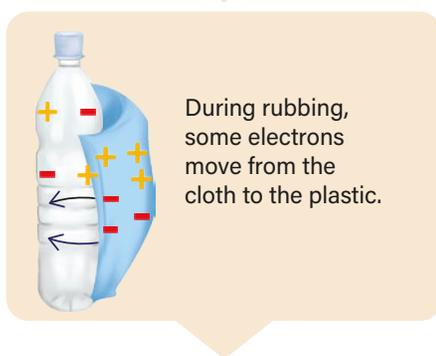
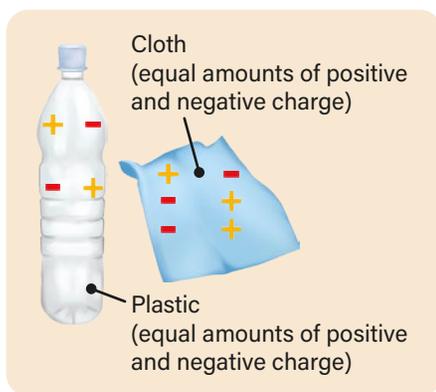
At the end of this lesson, I will be able to describe how charged particles move, and charged objects interact.

Key term

electrostatic shock: the rapid movement of charged particles from one object to another

Key idea: Scale and measurement

Figure 8.11: The opposite electrostatic charges in the atmosphere and the top of the building cause lightning to strike during a storm.



▲ **Figure 8.12:** When you rub plastic and cloth together, an electrostatic charge is made on both objects.

When two objects with the same charge are brought close together, the force between them pushes them apart – that is, it repels them. When two objects with opposite charges are brought close together, the force between them pulls them together – that is, it attracts them. When a charged object and a neutral object are brought close together, they attract.

Objects gain and lose electrostatic charge

When electrons move onto or off an object, it becomes charged. Some materials attract electrons more than other materials do. When these materials come into contact with a material that does not attract electrons as strongly, some electrons will move onto the electron-attracting material. For example, plastic attracts electrons more strongly than cloth does. So, if plastic and cloth are rubbed together, some of the electrons within the cloth transfer to the plastic. The plastic becomes negatively charged because it has more electrons than protons. The cloth becomes positively charged because it has more protons than electrons (see Figure 8.12).

Everyday items gain electrostatic charge

You can generate an electrostatic charge by walking around or touching items together. This is often called static electricity and is caused by friction between objects that transfer electrons between them.

An easy way to see this is to blow up a balloon and rub it on your hair. The material of the balloon attracts electrons more than your hair does, so electrons from your hair move into the material of the balloon, creating a slight negative charge. At the same time, your hair gains a slight positive charge because now it has more protons than electrons.



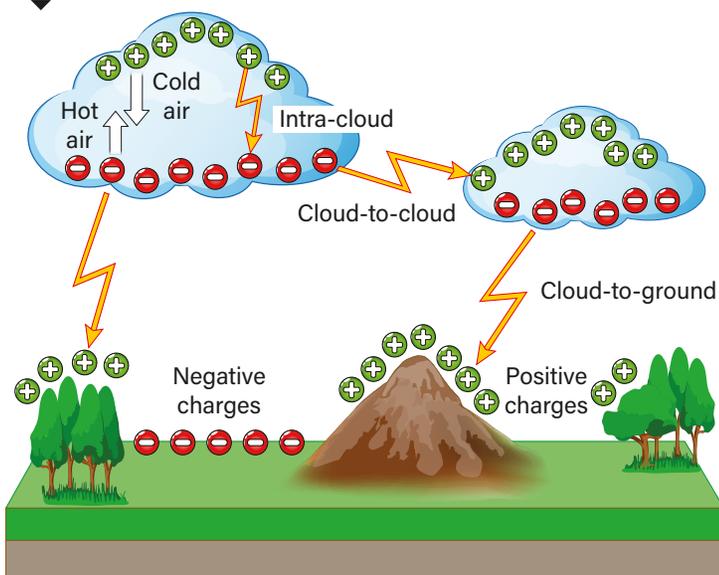
Figure 8.13: Rubbing balloons on your hair will create a slight positive charge in your hair, causing the strands to repel each other.

If the electrostatic charge is large enough, it can create a spark as the electrons move quickly back into the positively charged material. For example, if you take off a woollen jumper on a dry day, you may see small sparks.

Large-scale electrostatics can cause lightning

Lightning is an example of this movement of charge, or **electrostatic shock**, on a much larger scale. In a storm, two oppositely charged regions develop. The two charged areas can be within the storm clouds or in the clouds and the ground. These regions are separated by air, which acts as an insulator. When enough charge builds up, the air breaks down and there is a rapid movement of the charge. This discharge can be seen as lightning.

Figure 8.14: When lightning occurs, negatively charged particles jump to positively charged clouds or parts of the Earth.



Learning Ladder

Electricity

- 1 Identify and describe an example of when electrostatic charge transfers energy.
- 2 Describe how charging objects and moving electrons are related.
- 3 Construct a diagram to show how to positively charge an object. Show the object before and after charging.
- 4 Review Figure 8.13.
 - a Make two observations about electrostatic forces.
 - b Predict the charge on the balloon and on the hair.

Nature and development of science

- 1 a Identify a problem with making playground slides out of plastic in relation to electrostatic forces.
 - b Propose a solution to this problem.
- 2 Scientists created a way to paint cars by electrostatically charging the car itself, so that spray paint sticks to it. Explain the importance of multidisciplinary collaboration in creating this invention.
- 3 Explain how evidence for the structure of the atom has led to improved knowledge of electrostatics.
- 4 Undertake research to discuss how models of the atom have changed over time.
- 5 Analyse how a physicist and a chemist may collaborate to investigate the movement of electrons in atoms.

Questioning and predicting

p. 232

- 1 Identify which of the following would be the most suitable question to investigate scientifically.
 - A Does lightning strike the same place twice?
 - B Propose whether lightning can be controlled.
- 2 Review Figure 8.12. After the transfer of charges between the bottle and cloth, predict whether these objects will attract or repel each other, or neither.

Key idea: Scale and measurement

The triboelectric series is a scale showing objects ordered by how easily they gain or lose charge. Predict which of these materials would be most and least likely to gain a positive or negative charge: skin, wool, aluminium, paper, steel, rubber, plastic. Check your predictions by comparing your answers to an online triboelectric series.

Success criteria

- I can describe how charged particles move to cause a charge on objects.
- I can describe how electrostatically charged and neutral objects interact.

8.4 ▶ Electrical circuits

Learning intention

At the end of this lesson, I will be able to:

- identify the key features of circuits, and describe how a circuit transfers and transforms energy
- construct simple circuit diagrams to represent circuit design.

Key terms

circuit: a closed path for transferring electricity, including connecting wires and components connected to a power source

component: a device in a circuit that uses and transforms electrical energy

load: a component of a circuit that uses and transforms electrical energy

Key idea: Scale and measurement

Every device you own, from the simplest torch to the most sophisticated computer, works because of its electrical components. Electrical components are part of electric circuits, which can be shown as circuit diagrams.

A circuit must be a closed path

An electric **circuit** is a closed path for transferring electricity or electrical energy. A circuit consists of:

- an energy source, such as a battery or generator
- **components** that transform electrical energy into other forms of energy, such as a light bulb, motor, speaker or heating element
- wires that connect the components to the power source and each other, to make a complete path back to the energy source.

Electricity only flows through a complete circuit

Electric circuits can be open or closed. A closed circuit is also known as a complete circuit and allows electricity to flow. Any gaps in the circuit stop the current from flowing. Many circuits contain switches, which are used to open and close the circuit (Figure 8.15). When you turn on a light, the switch changes the open circuit to a closed circuit and allows energy to flow through the wires to operate the light bulb.

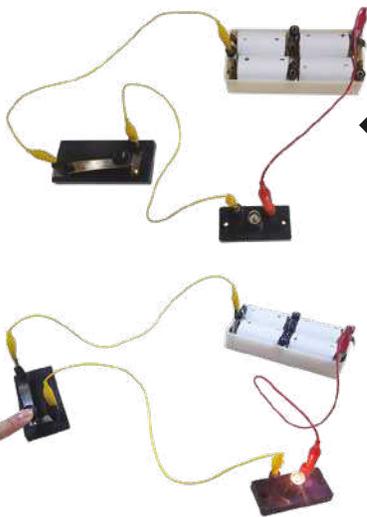
Electric circuits are energy converters

In an electric circuit, the electrons receive electrical energy from a battery or power source. Electrons move through the wires and components and carry this energy around the circuit. The wires and components are also known as a **load**, which is simply any component that uses electrical energy. The load could be a light bulb, a motor or a heater coil.

As electrons pass through a load, they transfer their energy to the component, which transforms that energy into another type. For example, a light bulb transforms electrical energy into heat and light energy. The electrons then continue through the circuit, returning to the battery, where they receive more energy and travel around the circuit again.

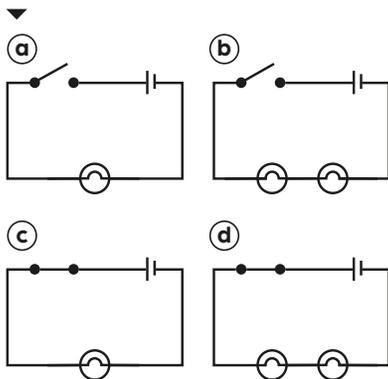
Electric circuits can be drawn as diagrams

An electric circuit can be recorded as a diagram. Circuit diagrams use symbols to show how the different electrical components are connected. Diagrams like those in Figure 8.16 record circuits that would be too confusing to show as pictures of each component. They are efficient to draw and easy to read, so circuits can be built quickly from them.



▼ **Figure 8.15:** Turning on a switch changes an open circuit to a closed circuit.

Figure 8.16: Circuit diagrams show the components of electric circuits in a simple and standardised way.



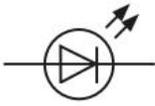
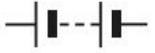
Circuit components are shown as standard symbols

Component symbols are nearly always shown in the same way. This means that anyone who knows these symbols can read a circuit diagram. Table 8.1 shows the symbols for the most common components.

When drawing basic circuit diagrams:

- 1 use a sharp pencil and a ruler
- 2 draw the symbols in the correct places; do not draw symbols at corners
- 3 use a ruler to connect the symbols with wires; wires should generally only change angles at 90°
- 4 make sure the wires do not cross
- 5 check the circuit by tracing from the battery through each component and back to the battery.

Table 8.1: Common electrical components and their symbols.

Component	Picture	Symbol
Open switch		
Closed switch		
Lamp/light bulb		
LED (light-emitting diode)		
Cell		
Battery (multiple cells)		
Wire		

Learning Ladder

Electricity

- 1 Identify the three main requirements when constructing a circuit.
- 2 Describe what occurs when electrons flow around a closed circuit.
- 3 Draw a simple circuit that includes each of the following components: battery, open switch, LED.
- 4 In Figure 8.16, identify and explain which circuits will allow electrons to flow around the circuit completely.
- 5 Select the components required to make the circuit for a simple torch and sketch it as a circuit diagram.

Use and influence of science

- 1 Single-use batteries do not last very long and therefore need to be replaced often. Identify a social, economic or environmental issue related to this problem.
- 2 Describe an example of how our knowledge of electricity and circuits has affected society.
- 3 Explain how the invention of LED lights has impacted the environment.
- 4 Waste batteries are an increasing problem. Discuss the impact of battery recycling collection points that are found now in many shops.
- 5 Analyse how advertising that explains the impacts of single-use batteries may shape people's decisions when buying batteries.

Questioning and predicting

p. 232

- 1 Identify which of the following scientific questions would be the most suitable to investigate.
 - A Would a circuit still work without a switch?
 - B Will increasing the amount of electrons in a circuit cause the light bulb to blow?
- 2 You observe that an LED in a circuit is not lighting up. Predict what may be causing this.

Key idea: Scale and measurement

Investigate some different uses of cells and batteries based on their size. Identify strengths and weaknesses for each type of cell or battery. Construct a table to present your results.

Success criteria

- I can identify the key features of circuits.
- I can describe energy transfer and energy transformation in circuits.
- I can sketch diagrams to represent electric circuits.

8.5 ▶ Energy in electrical circuits

Learning intention

At the end of this lesson, I will be able to explain voltage, current and resistance in electrical circuits.

Key terms

conductor: a material that allows the movement of charge

current: a measure of the flow of charged particles such as electrons in a circuit

insulator: a material that resists the movement of charge

potential difference: the difference in potential energy (voltage) between two points in a circuit

resistance: a measure of the opposition to flow of electric current

voltage: a measure of electric potential energy

Investigation 8.5A

Modelling a simple circuit, p. 363

Investigation 8.5B

Conductors and insulators, p. 364

Key idea: Scale and measurement

Electricity is a form of energy that is transported by the flow of electrons in circuits. For your television to work, electrical energy must be transported from the power plant where it is generated, into your home, and finally into your television. To understand how electricity works, we need to understand three properties of electricity: voltage, current and resistance.

Voltage is a measure of potential energy

Voltage is a measure of electric potential energy. When we measure voltage, we measure the **potential difference**, which is the difference in potential energy between two points in the circuit. Voltage has the symbol V and its unit is the volt (symbol V).

The bigger the potential difference between two points in an electrical circuit, the bigger the voltage. This is like the difference in height between two points on a rollercoaster (Figure 8.17). Higher voltages have more energy and can do more work, just as higher points on a rollercoaster have more energy or potential than lower points. The difference between these points on the circuit is the voltage or potential difference. The battery causes an increase in voltage because it is an energy source. Each component in the circuit causes a drop in voltage when it uses energy in the circuit.

If a higher voltage battery is used in a circuit, light bulbs glow more brightly. However, there is a limit to how much voltage a bulb can cope with. A bulb will fail or 'blow' if there is too much voltage in the circuit.

Current is the rate of flow of charge

Current is a measure of the rate of flow of charged particles (electrons) in a circuit. Current has the symbol I and its unit is the ampere (or amp) (symbol A).

In a circuit, charge can move in either direction, depending on which way the power source 'pushes' the charge. If you change the direction of the battery in a simple circuit, you change the direction of current. In a simple circuit, current flows from the positive terminal of the battery around the circuit and back to the negative terminal.

You can visualise current as small balls being pushed through a pipe (Figure 8.18). When a ball is pushed into one end of the pipe, a ball at the other end is pushed out. So, a small movement of one ball

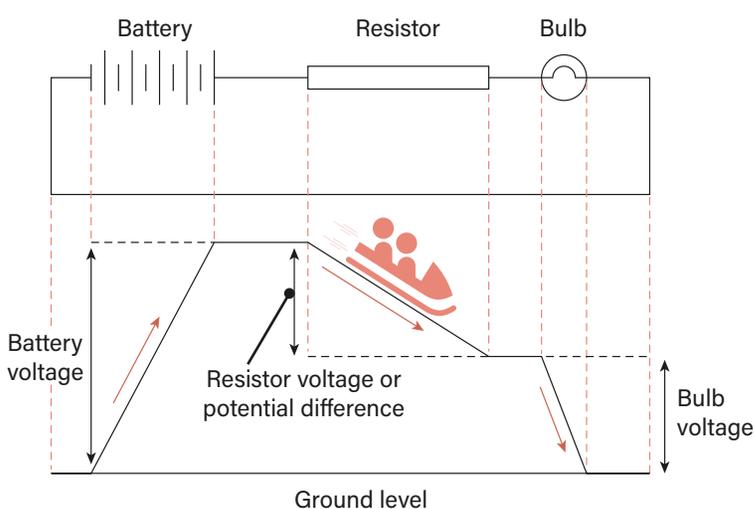


Figure 8.17: Voltage, or potential difference, is like the difference in height between two points on a rollercoaster.

can cause an action a long distance away. In this model, the balls are the charges (electrons), you are the battery pushing the charges, and the current is how fast you push the balls.

Some circuit components like LEDs are sensitive to current direction and others are not. Complicated or delicate components can be damaged by charge flowing in the wrong direction.

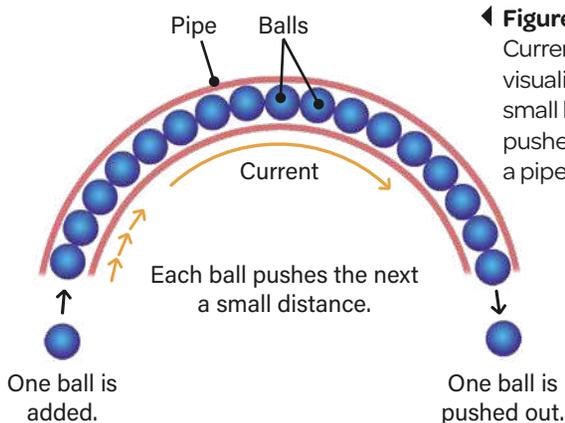


Figure 8.18: Current can be visualised as small balls being pushed through a pipe.

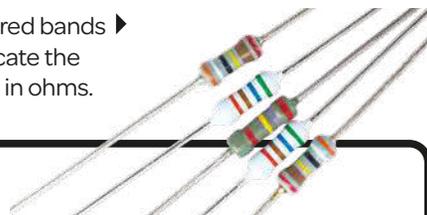
Resistance opposes voltage

Circuits are made up of wires and components that conduct electrical energy. Some materials, including most metals, such as copper, allow charge to flow more easily and are known as **conductors**. Other materials, such as rubber, resist the flow of charge and are called **insulators**. **Resistance** has the symbol R and its unit is the ohm (symbol Ω).

If voltage is the amount of 'push' given to a charge, then resistance is the opposing force. A component with resistance converts electrical energy into other forms of energy, such as heat, light or sound.

While each component in a circuit has resistance that 'slows' the flow of charge in the circuit, special components called resistors let you introduce exact amounts of resistance into circuits.

Figure 8.19: The coloured bands on these resistors indicate the value of the resistance in ohms.



Learning Ladder

Electricity

- 1 Identify these statements as true or false.
 - a Voltage is supplied by a resistor.
 - b Current always flows clockwise.
 - c Current gets used up as it goes around a circuit.
 - d Resistance is measured in ohms.
- 2 Describe the difference between voltage, current and resistance.
- 3 Design a circuit with a 12 V battery, and two light bulbs that each use 5 V, a resistor that uses 2 V and a switch. Label the voltage next to each component.
- 4 A torch bulb states it is rated as 8 V. The bulb is inserted into a torch with a 12 V battery. Propose what will happen.
- 5 Analyse the circuit you designed in Question 3. Describe what you noticed about the total of the voltage used in each component and the total input from the battery.

Nature and development of science

- 1 Electrical wires are dangerous if they have a lot of current flowing in them. Using your knowledge of resistance, suggest how you could protect people from touching the metal in electrical wires.
- 2 Identify two science areas where collaboration can improve innovation in electrical circuit design to develop faster computers. Explain your response.

- 3 One of two lights on your ceiling is brighter than the other. Which of the following would make the lights the same brightness?
 - A Increase the voltage going through the dim light bulb.
 - B Replace the dim light bulb with a higher-voltage one.
 - C Replace the bright light bulb with one that has a higher resistance.

Evaluating

p. 249

Read Investigation 8.5B and answer the following questions.

- 1 Identify the source of an error in this investigation.
- 2 Classify the error you identified as a systematic, personal or random error. Explain the reason for your answer.
- 3 Outline the key scientific concepts related to this investigation that you could use in your science-based explanations to support your findings.

Key idea: Scale and measurement

The units that voltage, current and resistance are measured in are all named after famous scientists. Conduct research into one of these scientists and explain their contribution to modern electricity.

Success criteria

- I can define 'voltage', 'current' and 'resistance'.
- I can explain how voltage, current and resistance behave in a circuit.

8.6 ▶ Ohm's law

Learning intention

At the end of this lesson, I will be able to use Ohm's law and conduct an experiment to determine the relationship between voltage, current and resistance.

Key terms

ammeter: a device that measures electric current

Ohm's law: a scientific law which demonstrates that the current through a conductor between two points is directly proportional to the voltage across the two points

voltmeter: a device that measures potential difference (voltage)

Investigation 8.6

Exploring Ohm's law, p. 365

Key idea: Scale and measurement

German physicist Georg Ohm (1789–1854) discovered the relationship between voltage, current and resistance in an electrical circuit. This relationship became known as **Ohm's law**.

Electrical current is proportional to voltage

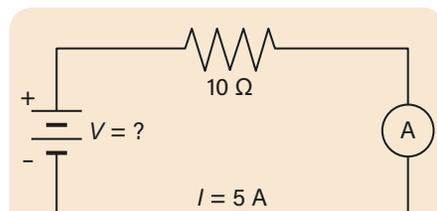
Ohm discovered that the relationship between current (I) in amps, voltage (V) in volts and resistance (R) in ohms can be summarised in the formula:

$$V = I \times R$$

For a fixed resistor (whose resistance does not change), increasing the current through the resistor increases the voltage across the resistor. Likewise, reducing the voltage across the resistor reduces the current flowing through it.

A useful way to remember Ohm's law is to use an Ohm's law triangle (Figure 8.21).

Figure 8.20: An example of a calculation using Ohm's law to find the value of the voltage



Find the voltage (V):

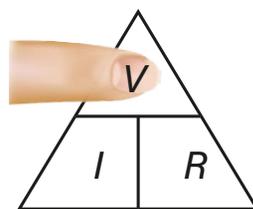
Resistance = 10Ω

Current = 5 A

Therefore:

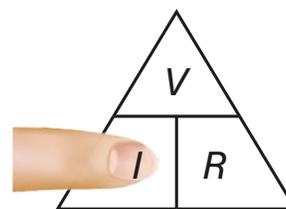
$$\begin{aligned} V &= I \times R \\ &= 5 \times 10 \\ &= 50 \text{ V} \end{aligned}$$

To find voltage:



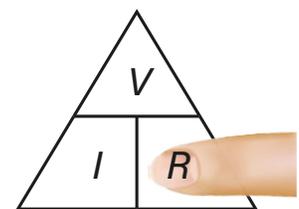
$$V = I \times R$$

To find current:



$$I = \frac{V}{R}$$

To find resistance:



$$R = \frac{V}{I}$$

Figure 8.21: If you know any two of the values for voltage, current or resistance, you can use an Ohm's law triangle to calculate the remaining one. Cover the value you need to know and use the other two values to complete the calculation.

Conductors with a fixed resistance are known as ohmic resistors. The resistance of non-ohmic conductors, such as LEDs, changes depending on the current passing through them.

Voltmeters measure potential difference

A **voltmeter** measures the potential difference, or voltage, across two points in a circuit. Before you can measure voltage, the circuit must be completed. Then, add the voltmeter so that the two probes are at the two points that the voltage will be measured across (Figure 8.22).

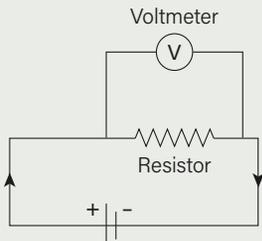
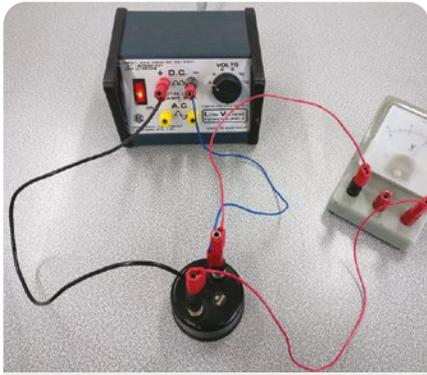


Figure 8.22: How to connect a voltmeter in parallel to take a measurement

Ammeters measure current

An **ammeter** measures current. An ammeter is connected as a part of the circuit so that the current has no other path but to go through the ammeter (Figure 8.23).

Ammeters must be connected in the correct direction – they do not work if connected backwards. Current flows from the positive terminal of a battery around the circuit and back to the negative side of the battery. Ammeters and voltmeters have red and black connecting points. The red connecting point should connect to the wires coming from the positive side of the battery and the black connecting point to the wires from the negative battery terminal.

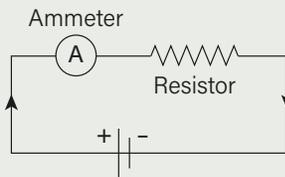
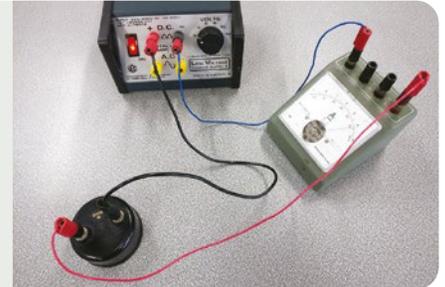


Figure 8.23: How to connect an ammeter in series to take a measurement



Learning Ladder

Electricity

- 1 Use the Ohm's law triangle to identify the equations for measuring:
 - a voltage.
 - b current.
 - c resistance.
- 2 a Describe the difference in how you would connect an ammeter and a voltmeter in a circuit.
b Outline why they are connected differently. Refer to how current and voltage act in a circuit.
- 3 Describe how you would construct a circuit to test the voltage of different light bulbs in a circuit.
- 4 Calculate:
 - a the current in a circuit if the voltage is 110 V and the resistance is 8 Ω .
 - b the voltage in a circuit if the current is 8 A and the resistance is 2 Ω .
- 5 A student constructed the following results table from their observations in an Ohm's law investigation.

Circuit	Voltage (V) Unit: volts (V)	Current (C) Unit: amperes (A)	Resistance (R) Unit: ohms (Ω)
1	10	25	
2	16	4	
3	24	7	

- a Identify and explain the three errors in this data table.
- b Copy, correct and complete the table.

Use and influence of science

Designing cheap, poor-quality electrical systems based on Ohm's law can have implications for some social groups.

- 1 Identify whether this is a social, environmental and/or economic issue.
- 2 Describe how society might be affected by the scenario in Question 1. Provide a reason for your response.

Questioning and predicting

p. 232

- 1 Select which of the following is the most suitable question for investigating the relationships in Ohm's law. Justify your answer.
 - A How will increasing the current affect the voltage in a circuit if resistance is kept the same?
 - B How will resistance change if thicker wires are used in a circuit?
- 2 Complete the following prediction based on Ohm's law: If you increase the voltage when _____ is constant, the _____ flowing through it will also increase proportionally.

Key idea: Scale and measurement

Research why measuring voltage, current and resistance, and using Ohm's law, is crucial to developing safe, reliable and efficient electronic products.

Success criteria

- I can describe the relationship between voltage, current and resistance.
- I can calculate relationships using Ohm's law.

8.7 ▶ Series and parallel circuits

Learning intention

At the end of this lesson, I will be able to compare the features of series and parallel circuits, including differences in voltage, current and resistance.

Key terms

parallel circuit: a circuit in which all components are connected between the same points in branches, so the current divides into more than one path

series circuit: a circuit in which components are connected in a line, so the current has only one path to take

Investigation 8.7

Series and parallel circuits, p. 366

Key idea: Scale and measurement

Before LED lights were used in Christmas lights, if one light bulb went out, so did the rest in the chain. The lights were connected in series, and a single broken bulb would stop the flow of electricity through the whole circuit. In a parallel circuit, the components work independently of each other.

In series circuits, components are connected one after another

When components in a circuit are arranged one after another, this is called a **series circuit**. There is only one path for the current to flow through. If you trace your finger over the circuit or diagram, you will pass through every component back to the start without retracing your path.

A series circuit needs to be complete for current to flow. If one of the components breaks or is removed, then the circuit is incomplete and no current can flow (Figure 8.24).

In parallel circuits, components are on different branches

In a **parallel circuit**, each component is on a different branch of the circuit. To check if components are connected in parallel, trace around the circuit. If you come to a point where you must choose between two or more branches, then the circuit is parallel.

In a parallel circuit, if a component in one branch breaks, the circuit can still be complete through the connections in the other branches. A bulb in this part of the circuit stays on even when a bulb in the other branch breaks (Figure 8.25).

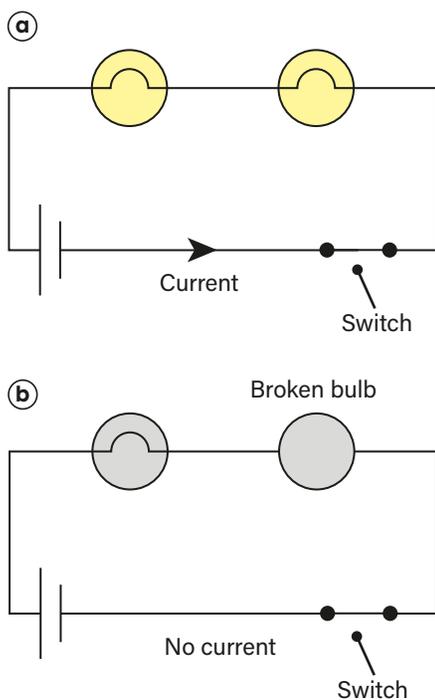


Figure 8.24: (a) In a complete series circuit, the bulbs light up. (b) A broken bulb results in an incomplete circuit and no bulbs light up.

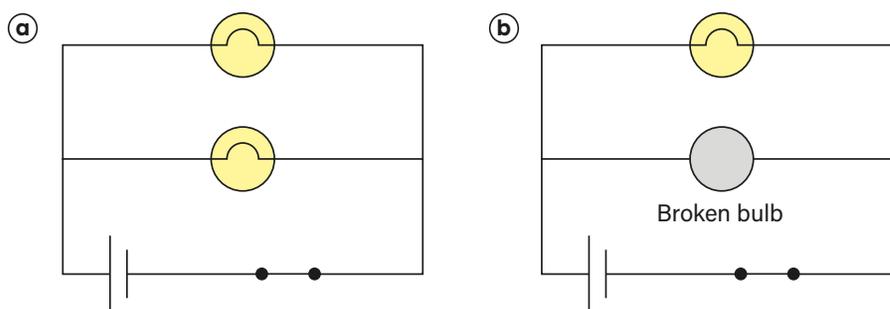
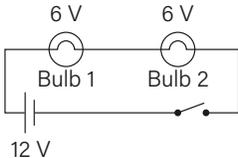
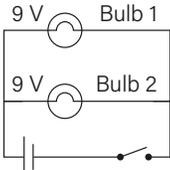
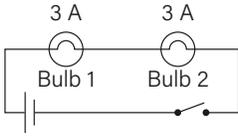
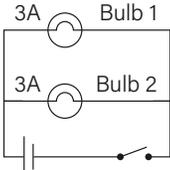


Figure 8.25: (a) In the complete parallel circuit, the bulbs light up. (b) A broken bulb does not result in an incomplete circuit and the other bulbs remain lit.

House wiring is an example of parallel circuits. Parallel circuits require more wiring than series circuits, but if one light bulb breaks or is removed, then the rest of the house lights can still work even if they are controlled by the same switch.

Table 8.2: A summary of voltage and current in series and parallel circuits

	Series circuit	Parallel circuit
Voltage	<p>The voltages across components add up to the total voltage supplied by the battery.</p>  <p> $6\text{ V} + 6\text{ V} = 12\text{ V}$ Bulb 1 + bulb 2 = total </p>	<p>The voltage across each component is the same.</p>  <p> $9\text{ V} = 9\text{ V} = 9\text{ V}$ Bulb 1 = bulb 2 = total </p>
Current	<p>The current is the same everywhere in the circuit.</p>  <p> $3\text{ A} = 3\text{ A} = 3\text{ A}$ Bulb 1 = bulb 2 = total </p>	<p>The current in each component adds up to the total current in the main branch containing the battery.</p>  <p> $3\text{ A} + 3\text{ A} = 6\text{ A}$ Bulb 1 + bulb 2 = total </p>
Observations	<ul style="list-style-type: none"> At the same voltage input, the brightness of the light bulbs in a series circuit will be dimmer, because the total energy (voltage) from the cell is shared equally between the globes in the circuit. As electrons pass through the bulb, they give half their energy to each bulb. Battery life will be shorter, as at any time a series circuit is using more total voltage from the battery. If one bulb breaks, all go out. 	<ul style="list-style-type: none"> At the same voltage input, the brightness of the bulbs in a parallel circuit will be greater, because the total energy (voltage) that goes into each branch is the same as the output of the cell. Electrons from the battery carry their full amount of energy into each branch and give it to the bulb to use the entire amount. Battery life will be longer, as at any time a parallel circuit is using less total voltage from the battery. If one bulb breaks, others stay on.

Learning Ladder

Electricity

- Identify the difference in the energy transfer taking place in series and parallel circuits.
- Classify the following as true or false.
 - In a series circuit, the voltage from the battery is the same as the voltage used by each bulb.
 - In a parallel circuit, the brightness of bulbs will be greater than in series, if the same energy is put into each.
 - If a bulb in series stops working, the current will stop flowing to all bulbs.
 - The current is the same in all parts of a parallel circuit.
- Construct a diagram of the following circuits.
 - Three bulbs in parallel
 - Two bulbs in series, and two others in parallel. (There is more than one answer to this problem.)
- A student observes that in their house one light goes out, but all the others have remained on. Predict the type of circuit design being used. Justify your response.

Nature and development of science

- When creating a string of party lights, suggest a solution to ensure that if one bulb breaks, the others will still work.
- Propose why multidisciplinary collaboration is important when designing lighting systems for buildings.

Evaluating

p. 249

A student designs an investigation to compare series and parallel circuits.

- Identify any assumptions they may make.
- Describe some systematic errors that may be present.
- Outline the key scientific concepts that will need to be explained in the investigation findings.
- The student claimed that the current from the battery in each type of circuit is the same as on each light bulb. Evaluate this claim.
- Evaluate the following conclusion for this investigation. *The results show that the total voltage across the battery in a series circuit is the total of the voltage across each bulb, but in a parallel circuit it is the same as the voltage across each bulb.*

Key idea: Scale and measurement

Design a small-scale circuit for a greeting card that, when opened, turns on a light and sets off a buzzer. If the light or buzzer breaks, the other should stay on. If possible, set up your circuit and test it in class.

Success criteria

- I can construct simple series and parallel circuits.
- I can compare the features of series and parallel circuits.

8.8 ▶ Key idea: Scale and measurement – electricity in the home



Figure 8.26: Electrical work in a house must be completed by a qualified electrician only.

Learning intention

At the end of this lesson, I will be able to describe household circuits, including circuit design, components required and electrical safety.

Key terms

alternating current (AC): current that periodically changes direction

circuit breaker: a device that cuts off electricity if there is a short circuit

direct current (DC): current that only flows in one direction

earth wire: a wire that connects household electricity circuits to the Earth

live or active wire: carries the electricity to the home

neutral wire: completes the household circuit back to the power supply

short circuit: when a fault occurs that creates a low-resistance pathway through which current flows

Investigation 8.8

Short circuits, p. 368

Key idea: Scale and measurement

Electricity is used in our homes and is delivered through scaled-up, or larger, versions of the circuits you have learnt about so far. But the voltage and type of electricity is different, making electricity at home much more dangerous!

Electricity in our home is alternating current

When electricity flows into our home, it is known as **alternating current**, or **AC**, with a voltage of 240 Volts. AC current changes direction many times per second. We use AC current in our homes because it can carry a lot more energy over long distances, making it useful for transporting energy to our homes and using it in many ways. AC current is dangerous because of the high voltage that can drive a high current. If it goes through your body, you could suffer a serious and deadly shock!

Direct current (DC) flows only in one direction. Direct current normally has lower energy, or voltage, and is safer than AC current. Appliances that use batteries are DC, as are many smaller appliances such as chargers for a phone. DC appliances usually have a small electrical converter in the power cord to change the AC electricity to DC.

Homes are connected to the electricity grid

Electricity is supplied to your home from the electricity grid, which connects all houses to the power stations in your area. Some houses may be connected to the solar panels on a roof instead, or to both the electricity grid and solar panels. Either way, electricity comes to the house through two wires:

- a **live or active wire** that carries the electricity from your power station to the home
- a **neutral wire** that completes the circuit back to the power station.

The electricity enters your house through the live wire, as electrons flow and carry the energy (as voltage). The energy is used in the house through various appliances (or loads), and the electrons then travel back down the neutral wire to get more energy from the power source. The process works in the same way as the working circuits described in Section 8.4.

When electricity enters the home, it goes through a meter that measures how much energy is used. The meter is used to calculate the cost of the electricity for the house. The meter usually has a main switch to turn off the household circuit.

Figure 8.27: Our homes are connected to the electricity grid.

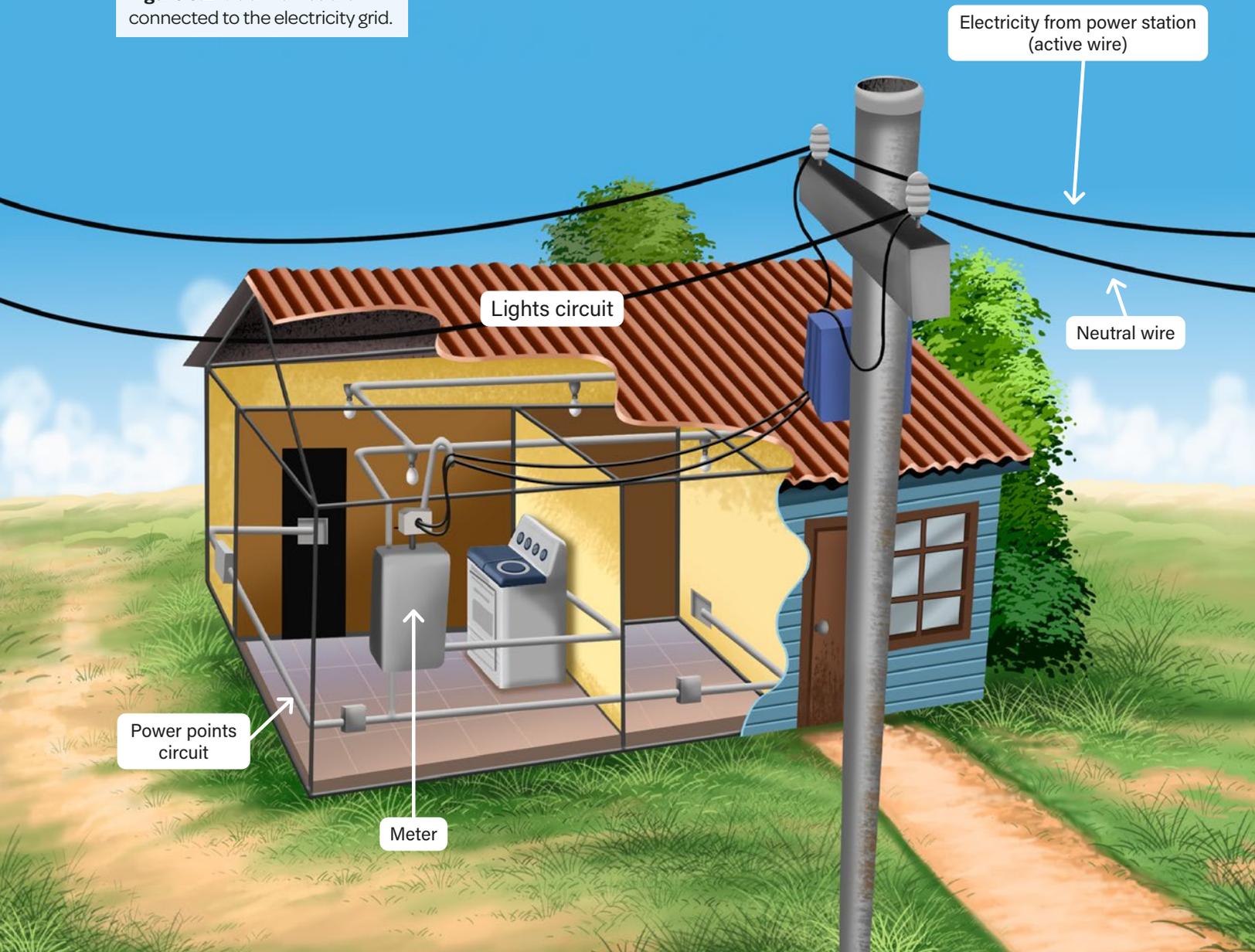
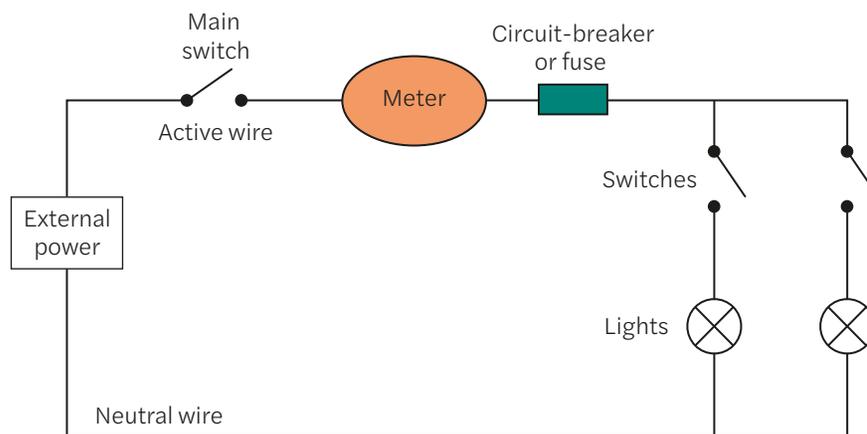


Figure 8.28: Diagram of a circuit inside the home



Inside the house are many parallel circuits

From the meter box where the electricity comes in, the live and neutral wires branch out into many separate circuits. These circuits carry the electricity to the lights and to the power points where you connect your appliances. Some circuits may only have one large appliance, such as a hot water heater, a heater or an oven. Switching on appliances allows the electricity to flow through the circuit to the appliance when the voltage is used, with electrons flowing back through the neutral wire to complete the circuit. Like the example in Figure 8.28, circuits inside the house are normally parallel. This ensures that if one appliance is switched off or stops working, others continue to operate. This is true for lights and for other appliances connected to power points.

Circuit breakers keep us safe

AC electricity is dangerous. For protection, household electrical circuits have built-in safety features, such as **circuit breakers** that cut off electricity if there is a short circuit. A **short circuit** occurs if two wires in a circuit touch when they should not. This could occur through faulty wiring or when an appliance is broken. When a short circuit occurs, electricity flows quickly through the easiest path, or the one with the least amount of resistance. For example, if you stick a knife in a toaster, electricity will flow through the knife rather than the toaster, as the knife has less resistance. This would potentially give you an electric shock. But before you get shocked, the circuit breaker responds to the very high, fast-flowing current that is created and switches off the circuit, saving your life.

A circuit breaker may also turn off if you overload the circuit with too many appliances at once.

When too much current is drawn through the circuit breaker, it switches off the circuit. Once you work out what is wrong, such as removing some appliances if the circuit is overloaded, or unplugging a faulty appliance, you can just switch the circuit back on.

Household circuits are connected to the earth

Most electrical appliances in your home have a three-pinned plug. One of these pins is the live wire, another is the neutral wire that we have discussed, and the third pin at the bottom of the plug is the **earth wire**. All appliances, including lights in your house, are connected to the earth wire. This green wire connects to a metal pipe or a metal stake in the ground somewhere outside your house. It is important, as it protects you when there is a short circuit.

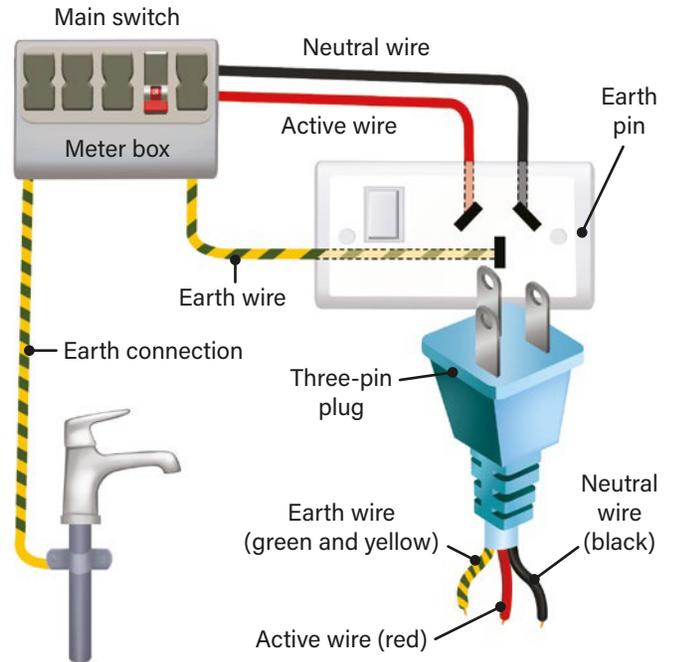
Most appliances, especially those with metal parts, have an earth wire connected to those metal parts. If there is a short circuit inside the appliance where a wire touches the metal, the current will flow through the earth wire and cause the circuit breaker to switch off the appliance. The current flows through the earth wire because it creates a path of low resistance that electricity prefers to flow through. If there were no earth wire, the metal parts of the appliance could remain live with electricity, and if you were to touch that appliance you would get a shock.

You may notice that some appliances – such as a hairdryer – will have only two pins and are missing the earth pin. These appliances must have a double layer of insulation to stop any wires from a short circuit touching the outside of the appliance. This protects you in a different way from a dangerous shock.

Figure 8.29: A circuit breaker in the household circuit has many switches, one for each parallel circuit, and a safety switch to protect you in case of a short circuit. The test button on the safety switch creates a short circuit to check that the safety switch is working.



Figure 8.30: A three-pin plug showing how power and the earth wire are connected in a household circuit



Learning Ladder

Electricity

- 1 Identify some typical energy transfers that occur in a household circuit.
- 2 Describe each of the following using the concept of current and voltage where relevant.
 - a The difference between AC and DC
 - b How household wiring is still a circuit
 - c Why there are many circuits inside a house
 - d Why the household circuit has a neutral wire that connects to the power supply.
 - e Why electricity in a household can be dangerous and the safety features households must have
- 3 Construct a diagram for a household circuit that has:
 - a four power points to plug in appliances.
 - b two independent circuits connected to the circuit breaker; one circuit has three lights, and the other has two power points and a ceiling fan.
- 4 A person observed that their air fryer kept on switching off the circuit breaker. Predict what might have caused this problem. In your response, ensure that you explain how current and voltage may be involved.
- 5 Review Figures 8.27 to 8.30. Identify the components shown and explain the purpose of each in household electricity circuits.

Nature and development of science

- 1 AC electricity can carry a higher voltage than DC current. Identify a problem associated with AC electricity.

- 2 Describe why it is important that scientists collaborate when designing appliances that use household electricity systems.
- 3 Explain how our understanding of electric shocks has led to improvements in home electrical safety.

Questioning and predicting

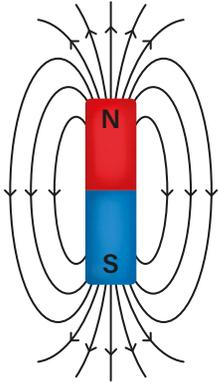
p. 232

- 1 Identify which of the following questions is the most appropriate for a scientist to investigate household electrical safety.
 - A What is the best metal to use for an earth wire?
 - B How many appliances can I plug in before the circuit breaker goes off?
 - C Is a double-insulated appliance safer than a three-pin plug appliance?
- 2 Based on what you know about short circuits, predict whether it is dangerous to have an appliance fall in water. Explain your answer.
- 3 Construct a scientific question to investigate a problem related to household electricity.
- 4 For your scientific question, develop a hypothesis that predicts the relationship between the variables.

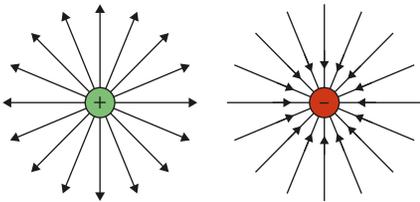
Success criteria

- I can describe household circuit design, including the components required for delivering household electricity.
- I can describe how household circuits are designed to keep people safe.

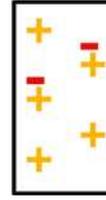
► Summary



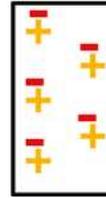
- Indirect forces work at a distance, without contact, as long as objects are in their fields.
- Magnetic forces affect objects made of metals with magnetic properties.
- Electrostatic forces affect objects that have an electrical charge.
- Field lines show the direction in which forces act in a field.
- An electromagnet uses electricity to make a magnetic field.



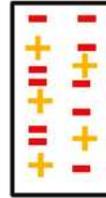
- Matter is made up of atoms.
- The nucleus of an atom is made up of uncharged neutrons and positive protons.
- Around the nucleus are negative electrons.
- Objects can have an electrostatic charge.



Positively charged = more protons than electrons

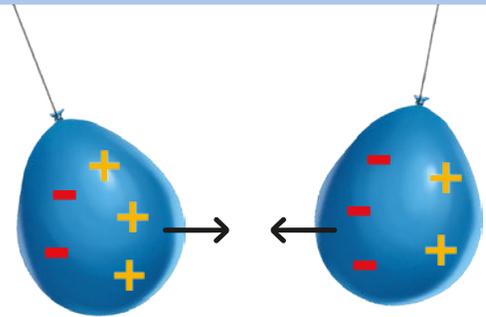


Neutral = same number of electrons and protons

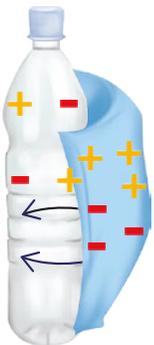


Negatively charged = more electrons than protons

- Objects with a like charge repel.
- Objects with an opposite charge attract.
- Neutral and charged objects attract.

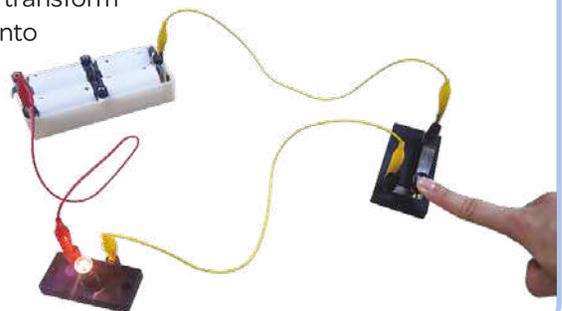


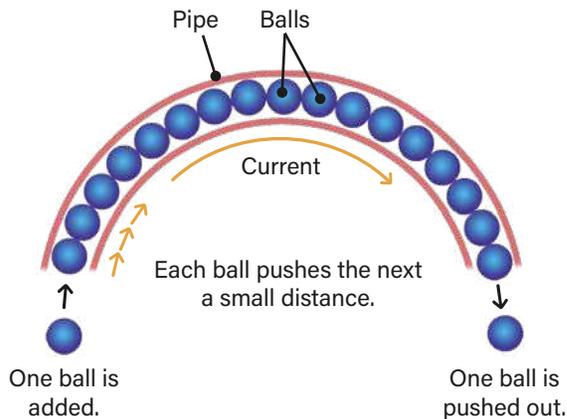
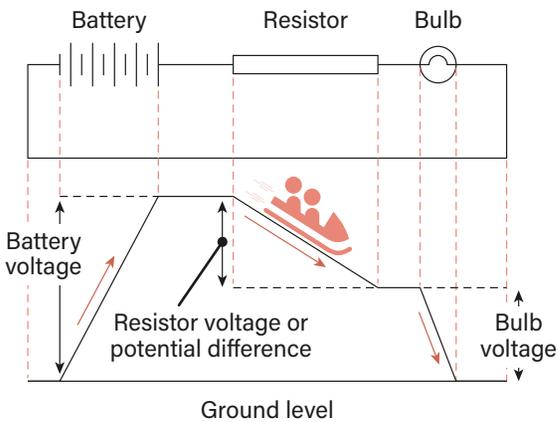
- Electrons can move between objects when they are rubbed, causing them to become charged.



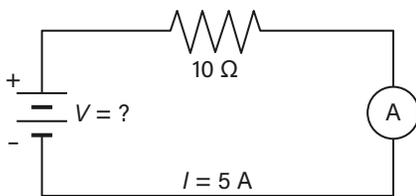
During rubbing, some electrons move from the cloth to the plastic.

- An electrical circuit is a closed path for transferring electrical energy.
- A circuit has:
 - an energy source
 - components that transform electrical energy into other energy
 - wires that connect the components.

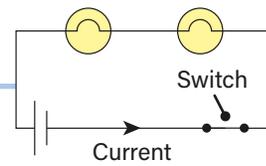




- **Voltage**, or potential difference, is the difference in potential energy between two points in a circuit.
- **Current** is a measure of the rate of flow of electrons in a circuit.
- **Resistance** opposes the flow of electricity. A component with resistance converts electrical energy into other forms of energy.
- Voltage (V): unit is the volt (symbol V).
- Current (I): unit is the ampere or amp (symbol A).
- Resistance (R): unit is the ohm (symbol Ω).



- Electrical current is proportional to voltage: Ohm's law states the relationship between current (I) in amps, voltage (V) in volts and resistance (R): $V = I \times R$

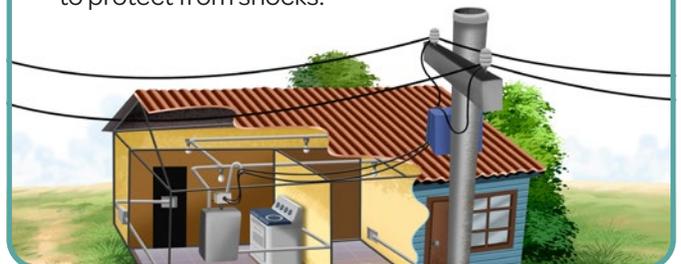


- In a series circuit, components are arranged one after another.
- In a parallel circuit, each component is on a different branch of the circuit.

	Observations
Series circuit	<ul style="list-style-type: none"> • At the same voltage input, the brightness of the light bulbs in a series circuit will be dimmer, because the total energy (voltage) from the cell is shared equally between the globes in the circuit. As electrons pass through the bulb, they give half their energy to each bulb. • Battery life will be shorter, as at any time a series circuit is using more total voltage from the battery. • If one bulb breaks, all go out.
Parallel circuit	<ul style="list-style-type: none"> • At the same voltage input, the brightness of the bulbs in a parallel circuit will be greater, because the total energy (voltage) that goes into each branch is the same as the output of the cell. Electrons from the battery carry their full amount of energy into each branch and give it to the bulb to use the entire amount. • Battery life will be longer, as at any time a parallel circuit is using less total voltage from the battery. • If one bulb breaks, others stay on.

Key idea: Scale and measurement

- Household electricity uses alternating current (AC) that constantly changes direction.
- Household electrical wiring includes parallel circuits. If one light goes off, others remain on.
- Circuit breakers (safety switches) switch off electricity if there is a short circuit, keeping us safe.
- The circuit is connected to an earth wire connected to a pipe or stake in the ground.
- Some appliances are double insulated to protect from shocks.



Masterclass

Steps in progression

1

2

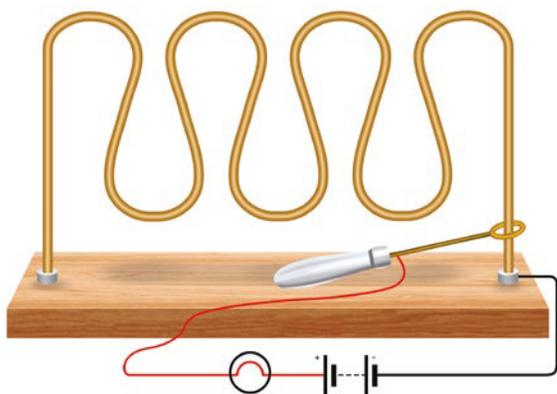
Science understanding	Electricity	Identify how energy is transferred in the circuit of a buzz wire game.	Describe how voltage and current allow this circuit to operate.
Science as a human endeavour	Nature and development of science	A student constructed a buzz wire game with a light bulb and buzzer, but the battery went flat very quickly. Propose a solution to this problem.	Describe the importance of multidisciplinary collaboration in designing portable electronic devices to access information anywhere.
	Use and influence of science	Identify whether the increased use of batteries in portable devices is a social, environmental and/or economic issue.	Describe how our knowledge of batteries has affected society.
Science inquiry	Questioning and predicting	Identify whether this question could be investigated scientifically: <i>If a second light is added to the buzz wire game in series, what will happen to the brightness of the bulbs?</i>	In the buzz wire game, if a buzzer and light are wired in parallel, predict what will occur if the light bulb is broken and the wires touch.
	Evaluating	A student is designing an investigation to compare the voltage and current in series and parallel circuits. Identify any assumptions that may be present in such an investigation.	Describe a systematic error and a personal error that may be present in the investigation outlined in step 1.

Electronic games

Electronic games are a part of life. They may be app-based games on your mobile phone or tablet, or they may be on gaming consoles or computer-based gaming platforms. Think of your favourite game. What does it cost? Is it enjoyable? Do you play alone or with others? Who developed it? What else do you know about this game?

Many of these types of games are quite complicated and rely on the electronics inside the device, sophisticated screens and programming to make them work. But the device must have a basic electronic circuit to allow it to turn on and off, or to recharge. Many of these devices are also now portable and contain batteries that can be recharged many times, allowing us to access and use them wherever we go. These scientific advances mean that we are more connected than ever and have access to entertainment like gaming no matter where we are. We are also using a lot more energy and batteries than ever before.

Figure 8.31: A simple circuit design for a buzz wire game showing a battery and light



Demonstrate your understanding

3

4

5

<p>Construct a diagram of the circuit shown as a scientific drawing and add a buzzer.</p>	<p>If you were to observe the current in your circuit at step 3, predict whether it would be the same, or different, at different locations.</p>	<p>Analyse the circuit you constructed in step 3 and explain the purpose of each component, including how it transforms or transfers energy.</p>	
<p>Explain how our knowledge of atoms and electrons relates to the flow of electricity in circuits.</p>	<p>Propose and discuss how Ohm's law may have developed over time with regard to understanding voltage, current and resistance.</p>	<p>Analyse how people with different perspectives are required to develop a game.</p>	
<p>Suggest an example of an environmental issue related to battery use and explain its impact.</p>	<p>The increase in battery recycling is a response to the number of batteries used and disposed of. Discuss the impact of this response.</p>	<p>Analyse how the increase in knowledge of batteries, their use and disposal is shaping policy about battery development and recycling.</p>	
<p>Construct a prediction in response to the question in step 1.</p>	<p>Develop a hypothesis about the question in step 1 that predicts the relationship between the investigation variables.</p>	<p>Review the question in step 1, and your prediction and hypothesis, and evaluate their validity. Justify your response.</p>	<p>Science how-to p. 232</p>
<p>Outline two key scientific concepts that would need to be used to explain the findings of the investigation in step 1.</p>	<p>After completing the investigation in step 1, the student claimed that the current was the same in all parts of both the parallel and series circuits. Create an evidence-based argument to evaluate this claim.</p>	<p>The student wrote in their conclusion for the investigation in step 1: <i>In series the voltage of the bulbs is always half that of the battery, while in parallel the voltage of the bulbs is the same as the battery.</i> Evaluate this conclusion.</p>	<p>Science how-to p. 249</p>

Some more basic electronic games use simple circuits, like the ones you have learnt about in this chapter. One example is the buzz wire game shown in the images on this page. This game demonstrates the basic concepts of electricity, including voltage, current and resistance, and series and parallel circuit design. Such simple games can be challenging and fun, and may increase your concentration and control.

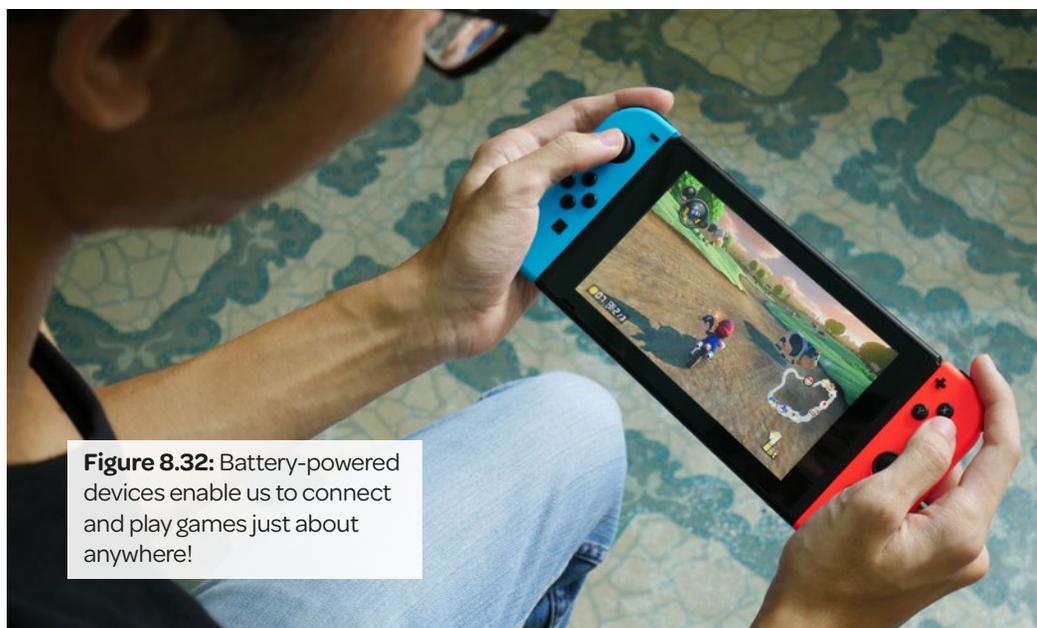


Figure 8.32: Battery-powered devices enable us to connect and play games just about anywhere!

Science how-to

Science skills are the tools you can apply when investigating the world around you. Learning how to use these skills will help you to understand scientific processes, ask relevant questions and communicate what you discover.

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S1

Command terms and response modelling



Command terms are the instruction words in a question. They tell you the approach to use when you answer it.

The command terms are listed alphabetically over the following pages. We have also included an example of how they would be used in a question and a sample response.

Account for	
Explanation	State reasons for; report on.
Sample question	Account for the movement of a ball down a slope.
Sample response	<i>A ball moves down a slope as a result of unbalanced forces. The force of gravity pushes down on the ball, causing it to accelerate down the slope. The force of friction between the ball and the slope is smaller than the force of gravity, so friction does not stop the ball from moving.</i>

Analyse	
Explanation	Identify components/elements and the significance of the relationship between them; draw out and relate implications; determine logic and reasonableness of information.
Sample question	Analyse the link between plate tectonics and earthquakes.
Sample response	<i>The movement of tectonic plates is responsible for the occurrence of earthquakes. At a transform boundary, plates slide past one another. These plates can stick, building up pressure before suddenly continuing to move, releasing large amounts of energy. At divergent boundaries, one plate is pushed under the other, down into Earth's mantle. The plates can release energy as they collide with one another. Earthquakes are caused by this release of energy. As the energy travels through Earth's crust as waves, it causes the 'shaking' vibrations that we know as earthquakes.</i>

Apply																												
Explanation	Use; employ in a particular situation or context.																											
Sample question	Apply your understanding of Linnaean classification to the following organisms. <ul style="list-style-type: none"> Orca Ring-tailed possum 																											
Sample response	<p>The Linnaean classification system classifies organisms from broad to specific categories. The organisms above would be classified as follows:</p> <table border="1"> <thead> <tr> <th>Category</th> <th>Orca classification</th> <th>Ring-tailed possum classification</th> </tr> </thead> <tbody> <tr> <td>Domain</td> <td>Eukarya</td> <td>Eukarya</td> </tr> <tr> <td>Kingdom</td> <td>Animalia</td> <td>Animalia</td> </tr> <tr> <td>Phylum</td> <td>Chordata</td> <td>Chordata</td> </tr> <tr> <td>Class</td> <td>Mammalia</td> <td>Mammalia</td> </tr> <tr> <td>Order</td> <td>Cetacea</td> <td>Diprotodontia</td> </tr> <tr> <td>Family</td> <td>Delphinidae</td> <td>Pseudocheiridae</td> </tr> <tr> <td>Genus</td> <td><i>Orcinus</i></td> <td><i>Pseudocheirus</i></td> </tr> <tr> <td>Species</td> <td><i>orca</i></td> <td><i>peregrinus</i></td> </tr> </tbody> </table>	Category	Orca classification	Ring-tailed possum classification	Domain	Eukarya	Eukarya	Kingdom	Animalia	Animalia	Phylum	Chordata	Chordata	Class	Mammalia	Mammalia	Order	Cetacea	Diprotodontia	Family	Delphinidae	Pseudocheiridae	Genus	<i>Orcinus</i>	<i>Pseudocheirus</i>	Species	<i>orca</i>	<i>peregrinus</i>
Category	Orca classification	Ring-tailed possum classification																										
Domain	Eukarya	Eukarya																										
Kingdom	Animalia	Animalia																										
Phylum	Chordata	Chordata																										
Class	Mammalia	Mammalia																										
Order	Cetacea	Diprotodontia																										
Family	Delphinidae	Pseudocheiridae																										
Genus	<i>Orcinus</i>	<i>Pseudocheirus</i>																										
Species	<i>orca</i>	<i>peregrinus</i>																										

Assess	
Explanation	Make a judgement about, or measure, determine or estimate, the value, quality, outcomes, results, size, significance, nature or extent of something.
Sample question	Assess the effectiveness of using solar energy to reduce household power costs.
Sample response	<p>Solar energy is energy from sunlight that is converted by panels into usable electrical energy.</p> <p>Arguments for:</p> <ul style="list-style-type: none"> Using solar energy can reduce or remove a household's reliance on obtaining electrical energy from non-renewable power sources. After the initial panel installation, solar energy does not cost anything to obtain, which means households will save money. Households can get credit for any unused solar electricity they send back to the grid, which further reduces their bills. <p>Arguments against:</p> <ul style="list-style-type: none"> Installing solar panels is expensive. To completely remove dependence on the power grid, householders need also to install expensive solar batteries to store the energy. Solar energy requires regular sunny weather to function effectively. Households may have minimal power after a series of cloudy or rainy days. <p>Assessment: Even though it costs a lot to set up at the start, solar power is highly effective at reducing household power costs. This is because power bills are much lower when you use solar energy.</p>

Calculate	
Explanation	Determine from given facts, figures or information; obtain a numerical answer showing the relevant stages in the working; determine or find (e.g. a number, answer) by using mathematical processes.
Sample question	Conduct a first-hand investigation to determine the distance travelled by a model car with wheels made from milk bottle caps. Calculate the average distance travelled over three trials.
Sample response	<p>The bottle cap wheel travelled 11 cm in trial 1, 9 cm in trial 2 and 13 cm in trial 3.</p> <p>This means the average distance travelled = $(11 + 9 + 13) \div 3 = 11$ cm.</p>

Figure S1.1: Renewable energy can be generated by wind, sunlight or water.



Compare	
Explanation	Recognise similarities and differences and the significance of these similarities and differences.
Sample question	Compare the use of renewable and non-renewable resources in energy production.
Sample response	<p><i>Similarities:</i></p> <ul style="list-style-type: none"> • Renewable and non-renewable resources can both be transformed into electrical energy. • Renewable and non-renewable forms of energy both rely on the construction of infrastructure (e.g. wind turbines and power stations) in order to produce electrical energy. <p><i>Differences:</i></p> <ul style="list-style-type: none"> • Renewable energy can be used without being depleted, while there is only a finite amount of non-renewable resources such as coal and oil. • Using renewable energy releases minimal pollutants into the atmosphere, while burning non-renewable energy releases pollutants and greenhouse gases such as carbon dioxide.

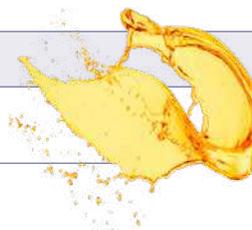
Construct	
Explanation	Make, build, create or put together by arranging ideas or items (e.g. an argument, artefact or solution); display information in a diagrammatic or logical form.
Sample question	Construct a poster, diagram or presentation to show your understanding of the factors that impact plant growth.
Sample response	Different versions of responses to this question are shown in the 'Presenting scientific information' section on page 261.

Define	
Explanation	Give the precise meaning and identify essential qualities of a word, phrase, concept or physical quantity.
Sample question	We learnt about elements and compounds in Chapter 3. Define the term 'compound'.
Sample response	<i>A combination of two or more different types of elements, joined together in a fixed ratio.</i>

Describe	
Explanation	Provide characteristics, features and qualities of a given concept, opinion, situation, event, process, effect, argument, narrative, text, experiment, artwork, performance piece or other artefact in an accurate way.
Sample question	A solvent is a substance, usually a liquid, that can dissolve another substance to make a solution. Describe how water acts as a solvent.
Sample response	<i>Water is a liquid that is able to dissolve the particles of other substances (solutes); it can become a solution with those dissolved particles by breaking their chemical bonds.</i>

Discuss	
Explanation	Present a clear, considered and balanced argument or prose that identifies issues and shows the strengths and weaknesses of, or points for and against, one or more arguments, concepts, factors, hypotheses, narratives and/or opinions.
Sample question	Discuss the use of non-renewable energy such as coal for large-scale electrical energy generation.
Sample response	<p>Coal has historically been the most widely used resource for power generation across Australia. It can provide reliable energy on a large scale, but using it has advantages and disadvantages.</p> <p>Advantages:</p> <ul style="list-style-type: none"> • Infrastructure in place at current power stations is set up to use and burn coal, meaning that it is an accessible and cheap method of providing power to many homes. • Most households are set up to receive electrical energy generated from already existing grids and power stations. <p>Disadvantages:</p> <ul style="list-style-type: none"> • Burning coal releases large amounts of carbon dioxide into the atmosphere, contributing to global warming. It also produces particles and pollutants, such as sulfur dioxide, which cause acid rain. • Coal is a non-renewable fossil fuel, meaning that if we continue to use it to generate energy at a large scale, we will eventually run out of this resource.

Distinguish	
Explanation	Make clear the differences between two or more arguments, concepts, opinions, narratives, artefacts, data points, trends and/or items.
Sample question	Elements, compounds and mixtures are discussed in Chapter 3. Distinguish between an element, a compound and a mixture.
Sample response	An element is a pure substance that is made up of only a single type of atom. Compounds are pure substances that are made up of a combination of two or more elements, held together in a fixed ratio. Compounds can only be broken down using chemical processes. A mixture is an impure substance, made up of two or more substances that are combined but can be physically separated.



Evaluate	
Explanation	Ascertain the value or amount of; make a judgement using the information supplied, criteria and/or own knowledge and understanding to consider a logical argument and/or supporting evidence for and against different points, arguments, concepts, processes, opinions or other information.
Sample question	Evaluate the use of wind energy as a power source, taking into account levels of pollution and reliability of the energy source.
Sample response	<p>Wind energy is a renewable form of electricity that uses turbines to transform kinetic energy into electrical energy.</p> <p>Arguments and evidence for:</p> <ul style="list-style-type: none"> • Wind energy is renewable, meaning it will not run out and it can be used continually. • Wind energy is 'clean' – it does not release unwanted pollutants into the atmosphere. • In favourable conditions, a single wind turbine is capable of supplying the power demands of over 300 homes. <p>Arguments and evidence against:</p> <ul style="list-style-type: none"> • Current infrastructure does not support the wide-scale use of wind turbines, and constructing them is expensive. • Wind turbines rely on environmental conditions – they need to be constructed in windy areas that are obstruction free, so that they can spin and generate electrical energy. <p>Judgement: Using wind energy as a power source is highly effective. While upfront costs to set up wind farms are high, the benefits outweigh these costs as they can power multiple homes and they reduce the amount of pollution in the atmosphere.</p>

Examine	
Explanation	Consider an argument, concept, debate, data point, trend or artefact in a way that identifies assumptions, possibilities and interrelationships.
Sample question	Examine this argument: 'We should gain 100 per cent of our energy needs from renewable sources.'
Sample response	<i>Renewable energy sources are ways of generating electrical energy that are able to be continuously renewed. These methods of electricity production typically do not produce waste products, making them better for the environment. However, our global energy demands are currently much higher than our ability to use renewable sources for all of our power generation. Instead, we should focus on putting more structures for renewable energy generation in place, so we can switch across from non-renewables without preventing access to electricity around the world.</i>

Explain	
Explanation	Give a detailed account of why and/or how, with reference to causes, effects, continuity, change, reasons or mechanisms; make the relationships between things evident.
Sample question	Explain how energy is transformed in a coal-fired power station to produce electricity for our homes.
Sample response	<i>Energy is able to be transformed within a coal-fired power station. Coal is burned, transforming the potential energy in the coal into heat energy. Heat energy heats water and causes it to boil, forming steam. The rising steam spins a turbine, transforming the heat energy into kinetic energy. This energy powers a generator, which transforms the kinetic energy into electrical energy, which can then be sent via wires to our homes. These energy transformations provide us with the electricity that our home appliances run on.</i>

Extrapolate	
Explanation	Infer and/or extend information that may not be clearly stated from a narrative, opinion, graph or image by assuming that existing trends will continue.
Sample question	Looking at the graph, extrapolate what will happen when the temperature of the water is 70 °C.
Sample response	<p><i>The graph shows that the amount of salt that can be dissolved by the water increases as the temperature increases. At 70 °C, the water should dissolve 35 g of salt, based on the trendline of the graph.</i></p>

Temperature of water (°C)	Amount of salt dissolved (g)
0	5
20	10
30	15
40	21
50	26
60	30
70	35 (extrapolated)

Figure S1.2: A graph showing how much salt is dissolved as water temperature increases

Identify	
Explanation	Recognise and name and/or select an event, feature, ingredient, element, speaker and/or part from a list or extended narrative or argument, or within a diagram, structure, artwork or experiment.
Sample question	As discussed in Chapter 2, identify the term used to describe the body system responsible for transporting oxygen to your cells.
Sample response	<i>Circulatory system.</i>

Investigate	
Explanation	Observe, study or carry out an examination in order to establish facts and reach new conclusions.
Sample question	n/a
Sample response	Investigating is covered in the 'Writing investigation reports' section on page 260.

Justify	
Explanation	Show, prove or defend, with reasoning and evidence, an argument, decision and/or point of view using given data and/or other information.
Sample question	Justify the use of water filtration in waste management.
Sample response	<p><i>Water filtration should be used in waste management. Filtering water means we can easily remove large particles that are not dissolved. This means that waste products such as plastics can be removed from waterways before the water is reintroduced to the environment.</i></p> <p><i>Filtering water can also remove tiny particles of sewage from waste. Using pumps, sewage is sent through microfilters that are capable of removing tiny solids and even some harmful bacteria. This improves water quality and stops harmful agents from being released into the environment.</i></p>

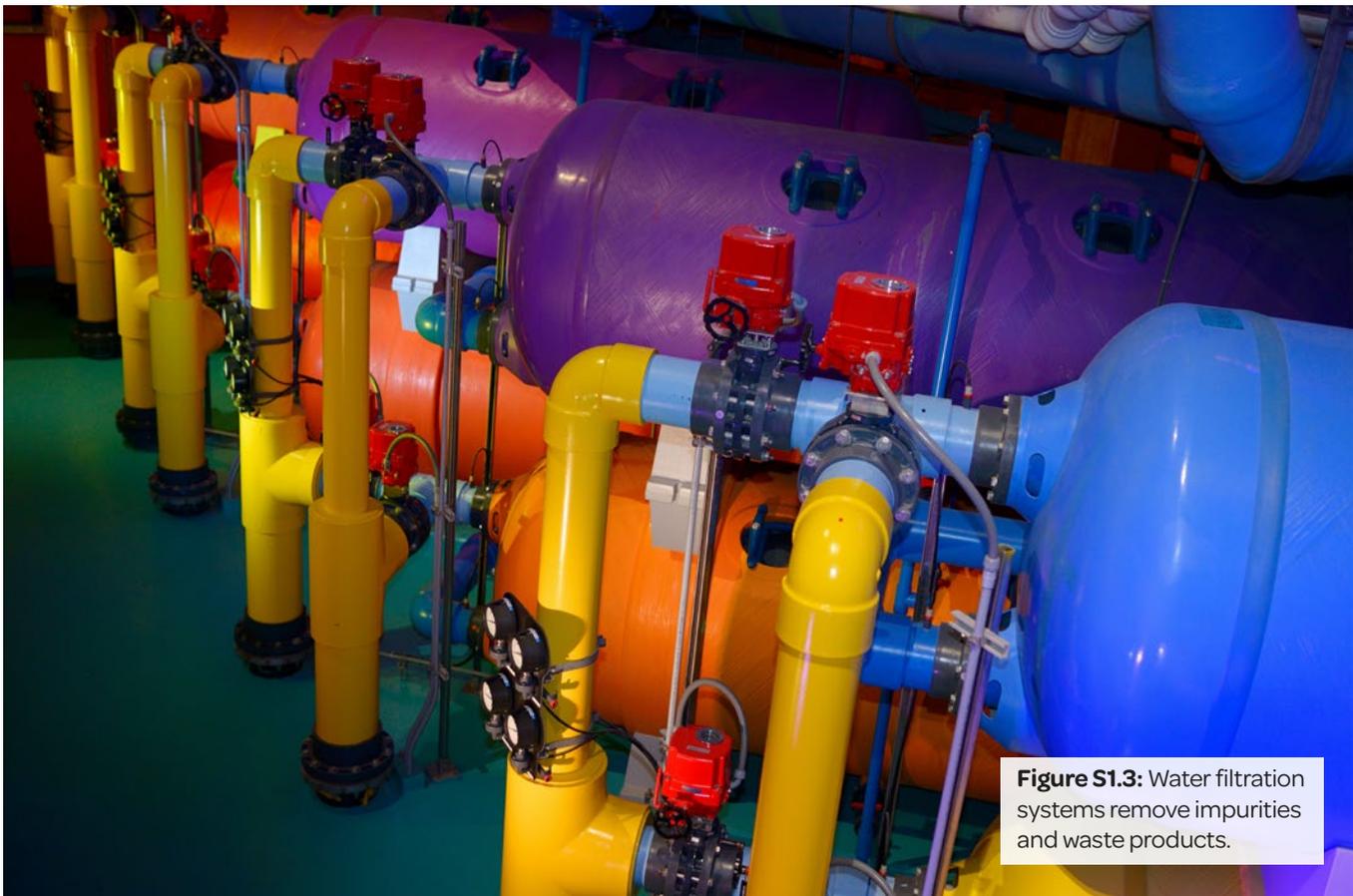


Figure S1.3: Water filtration systems remove impurities and waste products.

Outline	
Explanation	Provide an overview or the main features of an argument, point of view, text, narrative, diagram or image.
Sample question	Outline what happens at a convergent plate boundary.
Sample response	<i>Two tectonic plates collide, causing one to be pushed down under the other, with the edge of the plate at the subduction zone becoming a part of the magma in the mantle.</i>



Figure S1.4: We can test how sunlight affects plant growth.

Predict	
Explanation	Give an expected result of an upcoming action or event; suggest what may happen based on available information.
Sample question	Predict the effect of sunlight on the growth of tomato plants.
Sample response	<i>If a tomato plant receives a lot of sunlight, then it will grow taller than tomato plants that receive little light.</i>

Propose	
Explanation	Suggest or put forward a point of view, idea, argument, diagram, plan and/or suggestion based on given data or stimulus material for consideration or action.
Sample question	Propose a reason for wearing safety glasses when using a Bunsen burner to heat water.
Sample response	<i>When water heats up, it starts to boil and changes state from a liquid to a gas. This means that it bubbles and may splash out of its beaker. Wearing safety glasses prevents the water from splashing into your eyes and damaging them.</i>

Recall	
Explanation	Present remembered ideas, facts and/or experiences.
Sample question	Recall the components of cell theory.
Sample response	<p><i>Cell theory has the following components:</i></p> <ol style="list-style-type: none"> 1 <i>All living things are made up of cells.</i> 2 <i>Cells are the basic building blocks of life.</i> 3 <i>All cells come from cells that already exist.</i>

Summarise	
Explanation	Retell concisely the relevant and major details of one or more arguments, text, narratives, methodologies, processes, outcomes and/or sequences of events.
Sample question	Summarise the two groups that cells can be classified into.
Sample response	<i>Cells can be classified into two separate groups. One is prokaryotic cells, such as bacteria, that are simple cells that lack complex organelles. The other is eukaryotic cells, which contain complex organelles such as a nucleus and mitochondria.</i>

Key terms

accuracy: how close a measured value is to the true, exact value; how closely a recorded value matches the expected outcome of an investigation

anomalies: data points or findings that do not follow the normal trend or expected findings

controlled variable: variable in an investigation that must be kept the same for all trials. Only the independent variable should change, otherwise it is not a fair test

correlation: a relationship between two factors or variables that shows them changing together, in either the same or opposite way

data: facts and information collected for reference or analysis

data point (datum): a single identified element in a dataset

dataset: a collection of data, often from numerous trials related to a single factor

dependent variable: the thing that is measured in a first-hand investigation

ethical: in science, minimising harm to those involved, and ensuring investigations are conducted honestly and data is collected and recorded accurately

evaluate: judge value based on scientific evidence

fair test: a test where all variables are kept the same, except for the independent variable and the dependent variable

hazard: something that can harm living things, objects or the environment

hypothesis: a suggested explanation or prediction of a scientific problem that can be tested with an investigation

independent variable: the thing that is deliberately changed in a first-hand investigation

pattern (data): when data repeats in a predictable way

plausible: could be reasonably accepted based on available evidence

precision: how close measured values are to each other within a dataset

raw data: data that is collected directly from the investigation

relationship: a link between two factors

trend (data): when data moves in a general direction, usually up or down

true value: the actual, exact value of a measurement, error-free, which would be obtained if a perfect measurement were made

validity: when an investigation meets its intended purpose

variable: a factor in an investigation or a model that can be changed, measured or controlled

Science has its own skills that scientists use to conduct investigations and test their ideas. Science inquiry allows you to collect information and test your ideas about how different parts of the world work.

▼ **Figure S2.1:** Inquiry is a fundamental part of science.



Unpacking science inquiry

Science inquiry comprises five skills:

- 1 Questioning and predicting
- 2 Planning and conducting
- 3 Processing, modelling and analysing
- 4 Evaluating
- 5 Communicating.

This section will break down each skill for you – where to begin, how you can apply it as you learn more, and how mastering the skill will elevate your science learning.

The Learning Ladder and science inquiry

The Learning Ladder at the start of each chapter lists two of the five science inquiry skills (two have been selected for each chapter) and the five steps of progress for each of these skills.

Figure S2.2 shows the five science inquiry Learning Ladders, with step 1 being the first level and step 5 the final, most challenging level. You can only climb the ladder by mastering each step. This approach is called developmental learning and puts students in charge of their own learning progress.

Figure S2.2:
Start at step 1 and work your way up to mastery.

Learning Ladder

5	I can evaluate investigation questions and predictions for scientific validity	I can design and conduct reproducible investigations that consider safety, ethical and procedural factors	I can analyse processed data for patterns, trends, relationships and anomalies
4	I can develop a hypothesis that predicts the relationship between investigation variables	I can generate and record data with precision, using digital tools as appropriate	I can identify and discuss trends and/or patterns in a range of dataset representations
3	I can construct questions and predictions to investigate scientific problems	I can distinguish between variables to be changed, measured and controlled in an investigation	I can process data by using mathematical relationships and/or constructing graphs
2	I can make simple predictions based on what I know and observe	I can describe ways to minimise risks for a range of investigations	I can organise and display data using tables, keys and/or models
1	I can recognise questions that can be investigated scientifically	I can identify and select appropriate equipment for scientific investigations	I can identify data from tables and graphs
Steps in progression	Questioning and predicting	Planning and conducting	Processing, modelling and analysing
	Science inquiry skills		

Each section of this book contains a Learning Ladder question block. The questions relate to both content and inquiry skills. Question 1 corresponds to step 1, Question 2 corresponds to step 2, and so on.

The green headings mean these are science inquiry questions. They will test you on a specific skill, such as communicating. There is a page reference to the Science how-to section, where you can get more information on what is required at each step.

Next we will consider each science inquiry skill and break down what is required at each step of the Learning Ladder to develop your skills and achieve process mastery.

Learning Ladder

Organising matter

- 1 Complete the sentences below.
John _____ proposed that all _____ is made up of _____ and that atoms of a given _____ are identical. This became part of the _____ theory of _____.
- 2
 - a Describe the difference between an element and a compound.
 - b Describe, using examples, how a molecule can be an element or a compound.
- 3 Construct a labelled diagram of a helium atom which has two protons, two neutrons and two electrons.

Processing, modelling and analysing p. 240

- 1 Identify how many categories there are of pure substances. Name them.
- 2 Refer to Figure 3.6.
 - a Construct a table to organise the components (types of fruit) in the fruit salad mixture.

I can evaluate conclusions and claims with reference to conflicting evidence and unanswered questions	I can communicate scientific findings and arguments for specific purposes to specific audiences	5
I can create evidence-based arguments to justify conclusions or evaluate claims	I can use digital technologies to organise and communicate data and information	4
I can use science-based explanations to support investigation findings	I can prepare a variety of representations to communicate ideas and findings	3
I can describe different types of errors in an investigation method	I can select appropriate formats to communicate ideas and findings	2
I can identify errors and assumptions in an investigation	I can identify scientific terminology used to communicate information	1
Evaluating	Communicating	Steps in progression

Questioning and predicting

Questioning is the basis of all science. By asking questions, we can come up with ideas that we can test scientifically. Predicting scientific outcomes helps us to make better decisions. Predicting weather patterns can help people prepare for extreme temperatures, while predicting which illnesses might spread rapidly can help health-care workers adapt their treatments. By making accurate predictions, scientists can solve real-world problems and improve the quality of human life.

Step 1 I can recognise questions that can be investigated scientifically

Scientific questions contain one factor that we can change during an investigation and one factor we can measure. Doing this means that we can test the question by setting up a first-hand investigation. We usually write scientific questions in the following format:

How does *changing one factor* affect the factor that *can be measured*?

When checking if a question can be investigated scientifically, you need to check that only *one* thing changes in the question and that there is *one* thing you can measure. If more than one thing is changed, it is not possible to know which thing caused the effect. This is why only one thing can change, while everything else is controlled or kept the same. Controlled variables are discussed more in the 'Planning and conducting' section on page 236. Table S2.1 shows what to look for.

Table S2.1: What to look for when setting up an investigation

Question	Thing changed	Thing you can measure	Can it be investigated?
How does the amount of sunlight a plant receives affect how tall it grows?	The amount of sunlight the plant gets	How tall the plant grows	Yes
How can I look after my plants at home?	Many things – anything you do to look after your plants	None	No

The first question in Table S2.1 *can* be investigated, as there is one thing we can change and one thing we can measure. The second question *cannot* be investigated, as there is nothing to measure and many things we can change.

Figure S2.3: ▶
The changed factor (amount of sun) has an effect on the measured factor (how tall the plant grows).



Step 2 I can make simple predictions based on what I know and observe

When you are writing questions and making predictions, you need to ensure you are proposing things that are **plausible**. To help you predict something plausible, you can think back to experiences you have had or match the investigation to a relevant scientific theory you already know.



◀ **Figure S2.4:**
The observation of a hot-air balloon in the sky supports the prediction that heat can make objects rise.

For example, if you have a herb garden at home, you may have observed that the parsley grown in the shade does not grow as tall as the parsley in full sunlight. Add ‘because’ to your prediction (or ‘if ..., then ...’ statement; see step 4):

If a tomato plant gets more sun, then it will grow more because the parsley in full sun in my garden grows taller than parsley in the shade.

You can use this experience to predict how the amount of sunlight will affect the growth of tomatoes. Other examples of experiences that can help you to make predictions are:

- slipping on a puddle of water on tiles but not on a similar-sized puddle on concrete
- noticing someone bigger than you is faster when you roll down a steep hill on your bikes
- seeing a hot-air balloon in the sky and being told that the heat from the flames makes the balloon lift off the ground.

Step 3 I can construct questions and predictions to investigate scientific problems

We call the factors that we change and measure in the scientific question the **variables**. The factor that we change is called the **independent variable**. The factor that we measure is called the **dependent variable**. We want to see if there is a **relationship** between these two variables. In our scientific question structure, this looks like:

How does the *independent* variable affect the *dependent* variable?

For example, we may have the following scientific problem: The type of light bulb used impacts how much money we spend on our electricity bill based on the wasted energy. So, our question is:

How does the *type of light bulb used* affect how *hot it gets* when used in a circuit?

The independent variable is the type of light bulb. The dependent variable is the temperature it reaches. The additional step is to identify the relationship. In our example, we are testing the relationship between bulb type and temperature.

Figure S2.5: ▶
The type of light bulb used affects how hot it gets – but how?



The next step is to use scientific knowledge to help you make predictions. To link your prediction to scientific knowledge, you must match the content of your knowledge to the investigation factors. Your prediction statement will then be followed by a ‘because’:

If an LED light bulb is used, then it will stay at a lower temperature, because less energy is transformed into wasted heat energy.

The scientific knowledge you use can be general – you do not need to include specific details. However, it must be relevant to the investigation and the predicted effect.

Step 4 I can develop a hypothesis that predicts the relationship between investigation variables

Now that you can write and support a prediction in general, you can update your prediction with the specific variables of the investigation. This means we can also look at the relationship between the variables.

The following method will help you to formulate a scientific **hypothesis**:

- a Read the question.
- b Identify the independent variable.
- c Identify the dependent variable.
- d Identify some **controlled variables**.

Step 4 requires more detail on how you will change the independent variable to test your hypothesis, the relationship with the dependent variable and the predicted effect.

Once you have identified and understood your variables, include them in your prediction using the following template:

*If [the independent variable and the specific change],
then [the dependent variable and the predicted effect].*

So, your hypothesis will become:

*If the amount of sunlight a tomato plant receives is increased,
then its growth will increase by a similar amount.*

Step 5 I can evaluate investigation questions and predictions for scientific validity

Once scientific questions and predictions are constructed, their scientific **validity** must be **evaluated**. This means the investigation should measure what it intends to measure. Use the following steps to evaluate your question's validity.

- a Read the question and prediction.
- b Identify the independent and dependent variables. Is there one of each?
- c Identify some controlled variables.
- d Make a judgement on whether or not this is a good scientific question or prediction.
- e If needed, suggest any improvements and rewrite the question and/or prediction.

Table S2.2: Evaluating scientific questions by identifying the variables

1 How does the amount of sunlight a plant receives affect how tall it grows?	
Independent variable	Amount of sunlight the plant receives
Dependent variable	Height of plant
Controlled variables	None
Judgement	This is a good scientific question that changes only one factor; however, it needs to include the controlled variables to make it better, such as the type of soil, the amount of water given and the temperature of the room, all of which must be kept the same.
Improvement	This question could be improved by controlling the variables – the conditions that plants are grown in. For example, how does the amount of sunlight a plant receives affect how tall it grows when it is in the same conditions, including soil type, amount of water, temperature and fertiliser provided?
2 How does the type of light bulb used affect how hot it gets when used in an electrical circuit containing a 3V battery, a switch and one bulb?	
Independent variable	Type of light bulb
Dependent variable	Temperature of light bulb
Controlled variables	One – the circuit setup
Judgement	This is an excellent scientific question that includes one changed and one measured variable, as well as a way to control the investigation. No improvements are required.



Figure S2.6: There can be a variety of relationships between independent and dependent variables. Scientific knowledge and our own experiences can help us to predict what that relationship will be.

Planning and conducting

Planning will help you to come up with well-constructed investigations to answer scientific questions. A well-planned investigation should use appropriate scientific equipment, allow you to gather and record **data** precisely, and be reproducible. This allows you to safely and **ethically** conduct the investigation by following your plan.

Step 1 I can identify and select appropriate equipment for scientific investigations

When planning an investigation, you need to select the pieces of equipment to suit your purpose. As well as listing the equipment you will require to conduct the investigation, you need to ask yourself what the investigation will measure.

For example, if you are trying to measure the distance a toy car will travel in an investigation, you will need a toy car, and a ruler or a tape measure. To measure mass, you may need a set of scales, while temperature measurements would require a thermometer.

Go to the 'Laboratory equipment' section on page 289 to see some basic equipment illustrated.



Figure S2.7: When we perform investigations, we can measure mass using a set of scales. Scientific scales are very sensitive, and allow us to make very precise measurements.

Step 2 I can describe ways to minimise risks for a range of investigations

When conducting investigations, we must be able to identify **hazards**. To do this, you should look at the equipment you will use for your investigation and ask how it could cause harm, and describe how this risk of harm could be reduced. For example, see Investigation 4.6, 'Exothermic and endothermic reactions' (page 325), where the following equipment is used:

- safety glasses
- 5 test tubes
- funnel
- glass stirring rod
- sodium bicarbonate
- 5 mL of 1 M copper sulfate solution
- steel wool
- nitrile gloves
- test tube rack
- thermometer
- spatula
- 5 mL of 1 M hydrochloric acid
- 2 × 3 cm pieces of magnesium ribbon
- laboratory coat
- 10 mL measuring cylinder
- 15 mL vinegar
- 5 mL of 1 M sodium hydroxide
- 5 mL of 1 M sulfuric acid

How could this equipment cause harm, and what can you do to reduce the risk?

- The hydrochloric acid, sodium hydroxide and sulfuric acid could cause burns if they touch my skin or eyes. I can reduce the risk of harm by wearing safety glasses, gloves and long sleeves like a lab oratory coat to prevent these chemicals from coming into contact with my skin or eyes.
- The boiling water could injure someone's eye if it splashes. I can reduce this risk by making sure we all wear safety glasses.
- Someone could slip if the chemicals are spilled. I can reduce this risk by only measuring and adding chemicals to the test tubes at the bench.
- The measuring cylinder, stirring rod and test tube are made of glass. If they break, they could cut someone. I can reduce this risk by carrying them with two hands, and placing them towards the middle of the bench so they do not fall on the floor.

Risks you describe when planning an investigation can be structured in a table like Table S2.3. This shows us what we need to do in the investigation to reduce the risk of injury. By following the steps in the table, we are implementing the safe practices we have identified and reducing the risk for everyone.

Table S2.3: Reducing risks of injury when using chemicals and glassware

Hazard	Risk	Strategy
Hydrochloric acid	High likelihood of burns from acid if it contacts the skin or eyes	<ul style="list-style-type: none"> • Wear a lab oratory coat and gloves to prevent contact with skin. • Wear safety glasses to prevent acid splashing in eyes. • Only measure acid at the bench to prevent spills.
Sodium hydroxide	High likelihood of burns from base if it contacts skin or eyes	<ul style="list-style-type: none"> • Wear a lab oratory coat and gloves to prevent contact with skin. • Wear safety glasses to prevent base splashing in eyes. • Only measure base at the bench to prevent spills.
Glass beaker and measuring cylinder	Very high likelihood of cuts if glassware breaks	<ul style="list-style-type: none"> • Never run while carrying glassware. • Carry glass with two hands. • Place glassware away from the edge of the laboratory bench to prevent it from being knocked onto the floor.

Step 3 I can distinguish between variables to be changed, measured and controlled in an investigation

When planning an investigation, you need to be able to determine the independent variable that will be changed, the dependent variable that will be measured and all the controlled variables (the factors that must be kept the same). If anything changes other than the independent and dependent variables, it is not a fair test and the results will not be valid. You can determine your variables by asking the following questions:

- What am I trying to investigate?
- What one factor should I change?
- What one factor should I measure?
- What factors will I need to control?

For example, imagine you are conducting a first-hand investigation to separate salt from a salt-water mixture and wonder if the amount of salt will affect the time it takes.

- *What am I trying to investigate?*
How does the amount of salt in a salt-water mixture affect the time it takes to be separated?
- *What one factor should I change?*
I can see from the question that the amount of salt will need to be changed – this will be my *independent variable*.
- *What one factor should I measure?*
The question asks if the time will be different, so I should measure the time taken to separate the salt – this will be my *dependent variable*.
- *What factors will I need to control?*
To separate the salt, I will crystallise it by boiling away the water. So, each time, I should use the same:
 - amount of salt water
 - stopwatch to record the time
 - basin to evaporate the salt
 - Bunsen burner with blue flame.These will be my *controlled variables*.



▲ **Figure S2.8:**
A salt-water investigation – what will you change and what will you measure?

Figure S2.9:
Our aim shows us the purpose of our investigation. Here, we are investigating the link between the slope of a surface and how far a toy car can travel.



Step 4 I can generate and record data with precision, using digital tools as appropriate

As well as being safe, the data you collect in your investigations must also be recorded with **precision**. To check you are being precise in your measurements, you must ensure the following:

- A results table is constructed to record data from the independent and dependent variables of the investigation.
- The equipment used is appropriate for what you are testing (including using digital equipment where necessary).

You can use a checklist to help you confirm that your data is generated and recorded precisely. Your precise data-recording checklist might include:

- I constructed a results table that allows me to record data about the independent and dependent variables.
- I chose specific scientific equipment that allows me to record data precisely.
- I checked whether digital equipment was available to measure my variables.

Step 5 I can design and conduct reproducible investigations that consider safety, ethical and procedural factors

Before conducting an investigation, you will need to construct a plan so that you know what you are going to do. Plans are written in the form of scientific methods. They should be written as a series of numbered steps. They should also be written in the *third person*. Do not use *I, we or you.*)

In addition, your investigation should include:

- the *independent and dependent variables* and how you will measure them
- the *controlled variables* and how you will keep them the same
- evidence of *repetition*
- a way to *record the results*.

As an example, imagine we are investigating the following question:

Does the force a toy car is pushed with affect how far it travels across a flat surface?

Our method or procedure would follow the process below:

- 1 Collect all equipment.
- 2 Find a flat surface and place a line of tape down to mark the starting point of the car.
- 3 Place the car level with the starting line.
- 4 Gently push the car so that it starts to move.
- 5 Let the car travel along the surface until it comes to a stop.
- 6 Measure the distance the car travels from the starting line in centimetres, using a tape measure.
- 7 Record the distance in a results table.
- 8 Return the car to the starting line.
- 9 Repeat steps 3 to 8 two more times, applying the same force to the car.
- 10 Repeat steps 3 to 8 while applying medium and then firm force to the car to start its movement.

Having detailed steps in your method will make it reproducible; that is, it can be conducted by other scientists using the same method that you have used.

When conducting your method, you need to complete all parts of each step before moving onto the next one. So, for the first step of your investigation, you would collect all of the equipment you are going to need. While conducting your investigation, it is important that you are safe and your methods are ethical, so that your data can be trusted.

To check that your design is safe and ethical, ensure that:

- you or your teacher has conducted an appropriate risk assessment for the investigation
- the investigation is conducted honestly; no one has tried to skew the test or measurement to obtain a certain result
- the data is recorded exactly as measured.

You can use a checklist to confirm that your investigation is safe and ethical.

- I made a risk assessment that identifies at least three hazards and how to prevent them from happening.
- I conducted the investigation exactly as it was written in the method.
- I recorded the data I collected exactly as measured in a results table.

Figure S2.10:

We are studying whether the force applied affects how far a toy car will travel along a flat surface.



Processing, modelling and analysing

Information generated during a scientific investigation should be recorded in an organised way so that you can process it or use it to model an idea. Processing data involves presenting information in a way that clearly displays what you have found. This sometimes involves using models to show information in a different way to help make sense of it. Once data is processed or modelled, it should be analysed. Analysing data is like being a detective for numbers – uncovering the ‘clues’ told by the trends and patterns that emerge in the investigation data. This multilayered skill enables people to make sense of the data, make informed decisions, solve problems and predict future trends.

Step 1 I can identify data from tables and graphs

The first step in processing data is simply to recognise data that has already been organised into graphs or tables. When information is on display, you need to read what is presented carefully. Start with the title. What does it tell you? Then move onto headings and units. Ask yourself, what type of information am I looking at? And, what does the data tell me?

Table S2.4 is organised in a way that clearly displays information. From the title, we can recognise that the data will show us how plant growth is affected by sunlight. The headings indicate that measurements were taken in millimetres, and the values in the table show the growth of the plants in various amounts of sunlight.

Table S2.4: Effect of sunlight on plant growth

Plant and environment	Initial plant height (mm)	Growth after 1 week (mm)	Growth after 2 weeks (mm)	Growth after 3 weeks (mm)
Plant 1: no sunlight	181	0	-1	-3
Plant 2: indirect sunlight	175	1	2	4
Plant 3: direct sunlight	178	2	3	5

Step 2 I can organise and display data using tables, keys and/or models

Once you are comfortable recognising information from a table or graph that already contains data, you can use and even construct your own table to record data for a particular investigation using the following instructions.

- a Identify the independent and dependent variables.** Use these to write a descriptive title for the table. The descriptions representing the independent variable are listed in the left column and the dependent variable in the other columns. For example, in Table S2.4 we list the plants and how much sunlight they receive down the left column (independent variable). Then we have three headings for measurements at different times at the top of the other columns (dependent variable).
- b Determine how many rows and columns are required to construct the table.** The number of **datasets** indicates the number of rows required (plus one row for headings). In Table S2.4, we have three datasets: one for each of plants 1, 2 and 3. The number of columns depends on how many times you choose to take measurements. This could be based on time intervals, different items to measure or the number of trials you conduct. The example above uses weekly time intervals across three weeks, including the initial height. Units should be included in the headings when the data is a form of measurement; for example, (cm) or (mL).

- c **Construct a table with the appropriate number of rows and columns.** Ensure they are evenly spaced and that there is enough room to write the information clearly.
- d **Write headings to represent the variables.** The left column includes the plant number, as well as the specific plant environment. Ensure your headings give the reader a clear picture of the data collected, including the units of measurement used.



◀ **Figure S2.11:** Because plants grow slowly, it makes sense for you to measure in millimetres (mm) over three weeks.

The following example shows how to construct a table based on the investigation question:

How does the type of wheel – bottle cap, compact disc (CD) or washer – affect the distance travelled by a model car?

- a Identify the independent and dependent variables. Use these to write a descriptive title for the table.
The independent variable is the type of wheel, because this is the thing that changes. We will measure the distance travelled, so that is the dependent variable. A good title is 'Effect of wheel type on distance travelled'.
- b Determine how many rows and columns you need.
There are three types of wheels, so there will need to be three rows for recording data, plus heading rows. We can measure distance in centimetres (cm). We won't measure the time it takes. We think it is best to run three trials and then determine an average distance. One column is required for each trial, as well as one for the average, plus one for the wheel types.
- c Construct a table with the appropriate number of rows and columns.
- d Write headings to represent the variables. Remember: the independent variable belongs in the left column and the dependent variable goes along the top, with its unit of measurement.

Now you are ready to conduct the investigation and to record the data in an organised way, as shown in Table S2.5.

Table S2.5: Effect of wheel type on distance travelled

Wheel type	Distance travelled (cm)			
	Trial 1	Trial 2	Trial 3	Average
Bottle cap	11	9	13	$(11 + 9 + 13) \div 3 = 11$
CD	33	31	35	33
Washer	26	20	32	26

Note that in the cells where we show the averages, we only show the process for calculating the average once. For more information, go to the 'Calculating averages' section on page 275.

Step 3 I can process data by using mathematical relationships and/or constructing graphs

The next step is to process your data and show it in a graph. Sometimes you will complete calculations, like determining averages as shown in Table S2.5, which are then graphed instead of the **raw data** points. This allows you to show mathematical relationships in the data. Graphs are useful for displaying data, as they can be easier to understand and interpret. The three graphs we will use most often in science are the column graph, the line graph and the scatter plot, shown in Figure S2.12.

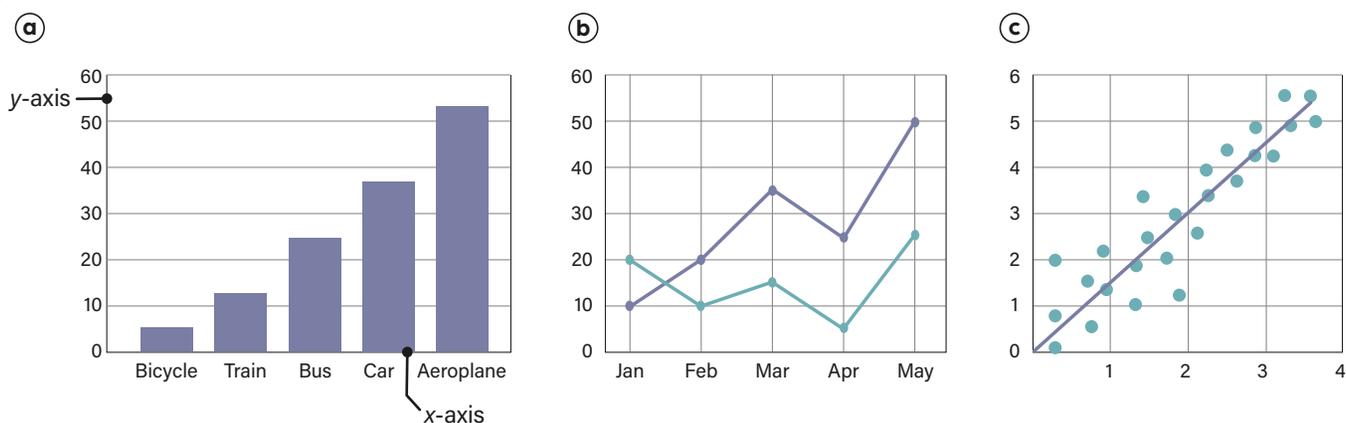


Figure S2.12: Three types of graph used in science: (a) a column graph showing the x- and y-axes; (b) a line graph; (c) a scatter plot, with a 'line of best fit' running through the middle

Figure S2.13 is a column graph of the results of the model car investigation. The annotation describes how to construct the graph.

- (a) Determine the range of the axes based on the data you have collected.

Write the dependent variable on the *y*-axis (vertical axis) and the independent variable on the *x*-axis (the horizontal axis).

Plot the measurements along the *y*-axis and the wheel type along the *x*-axis. The lowest data value from our averages is 11. The range of the *y*-axis must begin below this value. We could choose 10, 5 or 0, but it is good to start at 0 for simplicity. The largest data value is 33, so the highest value on the *y*-axis must be higher than that, such as 35.

- (b) Use a ruler to draw the axes and select the space between values. Since the *y*-axis will be spread from 0 to 35, it makes sense to count by fives up the axis. Avoid writing every number between 1 and 35, as this will make the graph too cluttered.

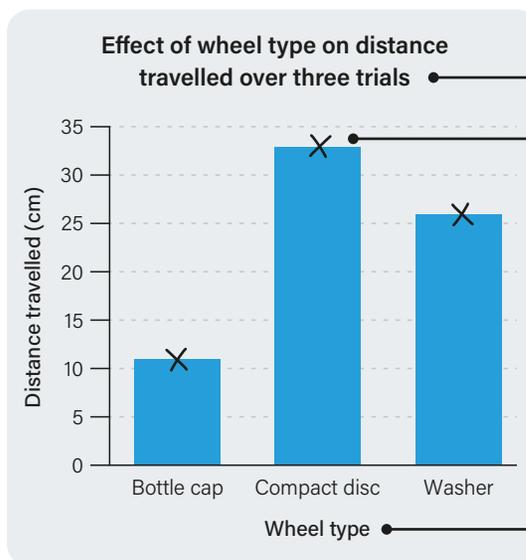
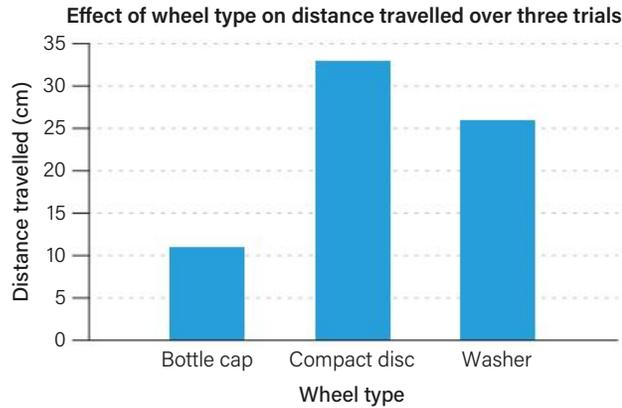


Figure S2.13: A column graph of the results of a model car investigation

- (c) Write the title, label the axes and plot your points on the graph – the graph title can be the same as the title of your table. Be sure to include the independent and dependent variables, not only in the title but also on the axes labels. Include the unit of measurement, if needed, on each axis label.
- (d) Draw your graph – a column graph requires you to draw and shade the columns. (A line graph means you connect the points in a line, while a scatter plot graph requires you to draw a 'line of best fit' that represents an average of your points.)

Categories of factors like the wheel type are best represented in a column graph, as shown in Figure S2.14. If measuring continuous time is involved, a line graph with connected points is best. If both the independent and dependent variable values are numbers, a scatter plot is best. A scatter plot includes a 'line of best fit', to show the **trend**.



◀ **Figure S2.14:** An example of a column graph using data from Table S2.5

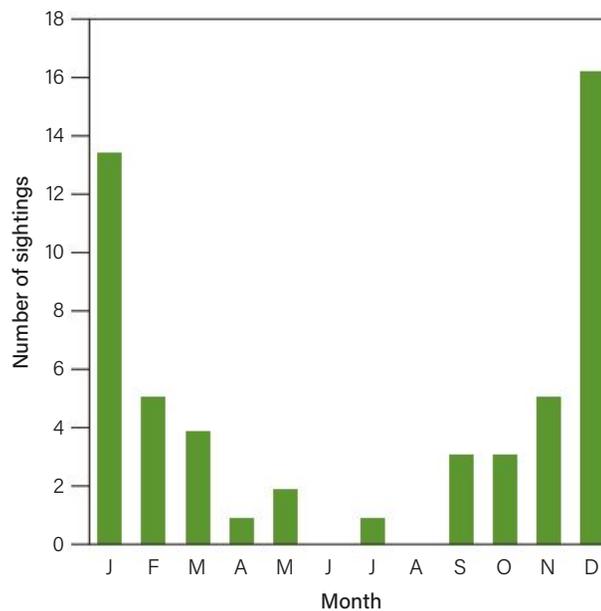
Step 4 I can identify and discuss trends and/or patterns in a range of dataset representations

A trend is shown by the line or bars in your graph moving in a general direction, usually up or down, as shown in Figure S2.15. A **pattern** is when the data repeats in predictable ways. Sometimes your data has no clear trend, so your visualisation will show random values all over, or there may be a sideways trend (a horizontal line).



◀ **Figure S2.15:** The green line is trending up, while the red line is trending down.

Figure S2.16 is a graph of snake sightings. It does not show a trend across the whole year. It shows a trend downwards from January to June and a trend upwards from July to December.



◀ **Figure S2.16:** Snake sightings, average per month

To recognise patterns, look for recurring values or repeating shapes. For example, Figure S2.16 does not show a year-wide trend, so the next thing you look for is a pattern. It is clear that there are more snake sightings in the warmer months, and not many at all in winter. This is a pattern that we would expect to see year after year.

It is clear that the pattern in Figure S2.16 is that snake sightings trend downwards in the first half of the year and upwards in the second half. The trends alternate in a repeating pattern each year.



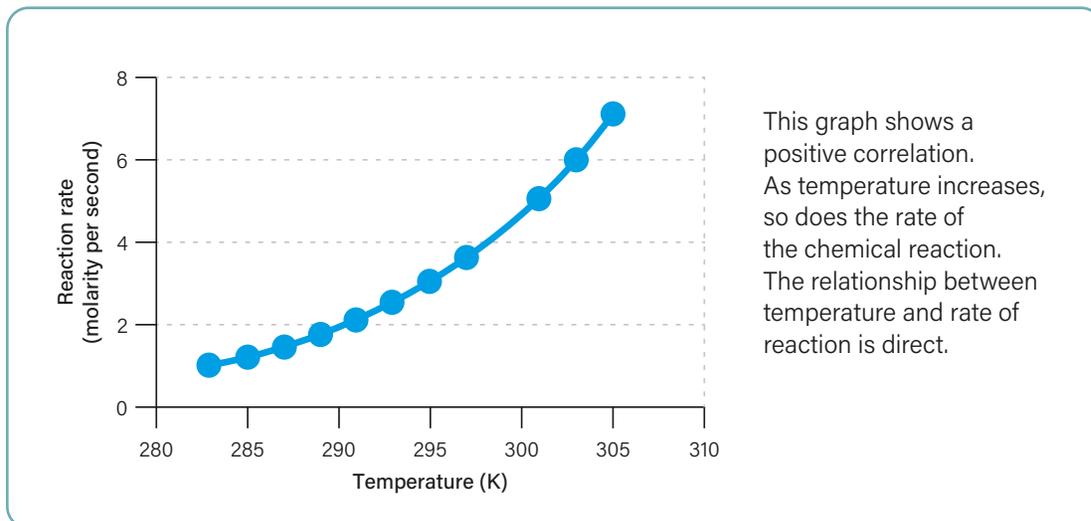
Figure S2.17: The number of snake sightings increases with average temperature across the year.

Next, we have to link any trends to the variables of the investigation. The relationship between the variables in an investigation is called the **correlation**. Identifying the correlation enables you to then describe the relationship between the dependent and independent variables.

- *Positive correlation*: the relationship between variables is direct. This means that if the value of one variable increases, the value of the other variable also increases, and vice versa.

Figure S2.18: ▶

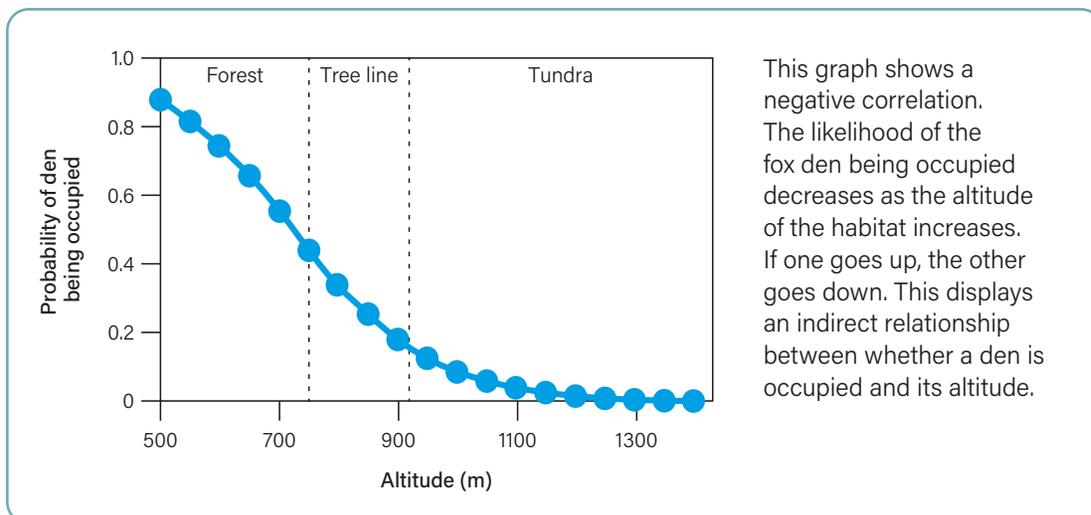
A line graph of reaction rates in an investigation, showing a positive correlation



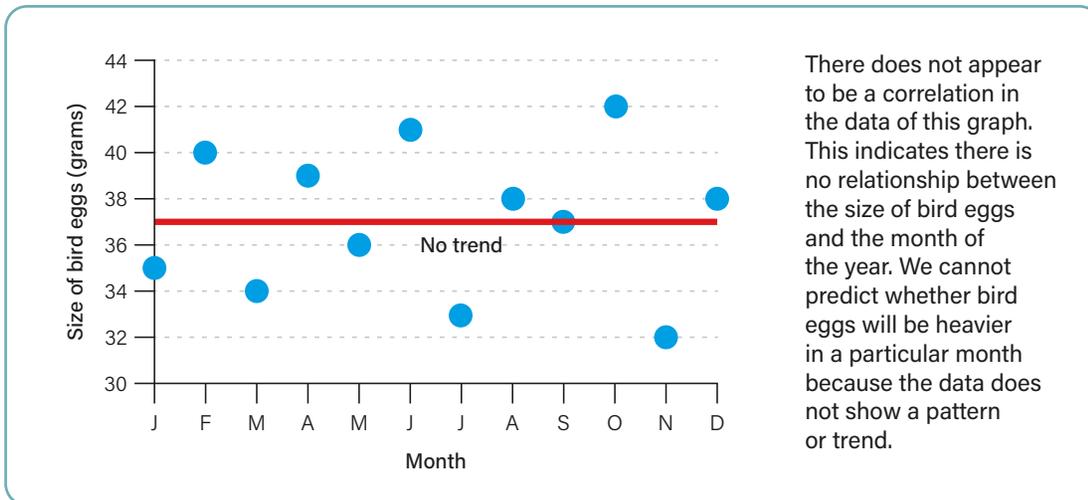
- *Negative correlation*: the relationship between variables is indirect. This means that if the value of one variable changes in one direction, the value of the other variable does the opposite.

Figure S2.19: ▶

A line graph of fox den occupation rates, showing a negative correlation

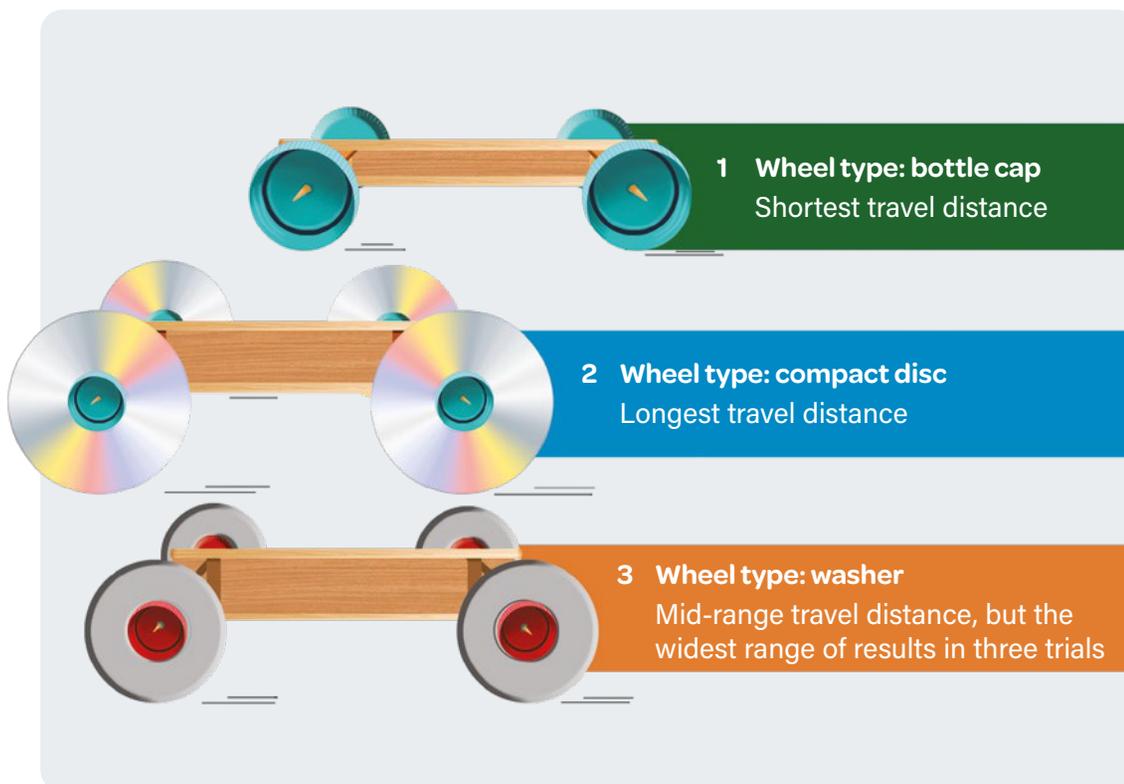


- *No correlation*: there is no apparent relationship between the variables.

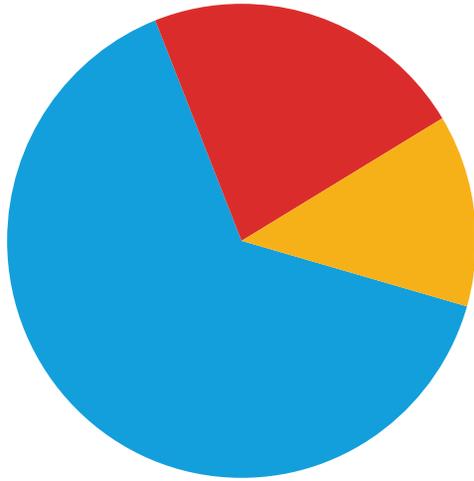


◀ **Figure S2.20:**
A graph of the mass of bird eggs and month laid

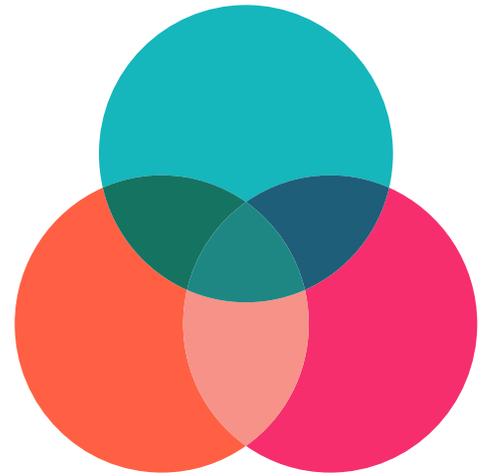
Once patterns and trends are identified, datasets can be represented in numerous other formats. You should choose an appropriate representation of your information, just like picking the right tool for a job. Figures S2.21 to S2.25 show some ways you can visually communicate the information.



◀ **Figure S2.21:**
An infographic showing the results of the model car investigation from step 3



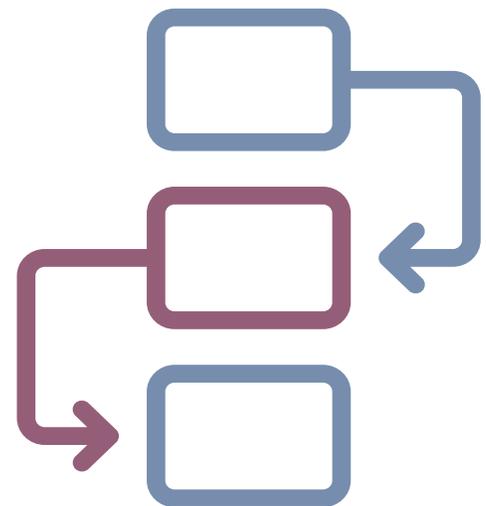
▲ **Figure S2.22:**
A pie chart is best for looking at the parts that make up a whole.



▲ **Figure S2.23:**
A Venn diagram is used to compare similarities and differences.



▲ **Figure S2.24:** A word cloud showing the magnitude of results of the car investigation from step 3



▲ **Figure S2.25:** A flow diagram can be used to show how one thing moves or transforms to another.

Step 5 I can analyse processed data for patterns, trends, relationships and anomalies

Trends and patterns across datasets in conjunction with scientific knowledge can be used to identify relationships between variables. We can then ask: Why is one variable affected by another variable in this way? The analysis of trends, patterns and relationships leads to scientific findings and conclusions.

For example, in Figure S2.19 the negative correlation between the fox den being occupied and altitude is linked to habitat theory and the effect of altitude on living conditions for the fox. As altitude increases, temperature and access to food decreases. These are reasons for why the den is less likely to be occupied at high altitudes, especially in winter.

Often, the information used to explain relationships between variables is aligned with the information used to inform predictions made at the start of an investigation.

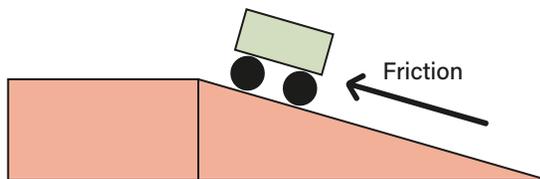
As scientists, we can identify scientific findings based on the data that emerges from an investigation or study by:

- a stating the relationship between the specific variables, based on the data.

This finding can then be generalised by:

- b replacing the terms specific to the investigation with general terminology, so it can be applied in a variety of contexts.

For example, if you investigate the effects of friction on the time it takes an object to reach the bottom of a ramp, you could use a toy car as the object, and ramp surfaces with varying amounts of friction, such as glass and wood. The results would show that the car reaches the bottom more quickly when rolled down the glass ramp than the wooden ramp. You can then use the points above to identify a finding.



◀ **Figure S2.26:**
Investigating
the effects
of friction

- a State the relationship between the specific variables, based on the data.
When the car rolls down the wooden ramp with more friction, it stops sooner than when it rolls down the glass ramp with less friction.
- b Replace the terms specific to the investigation with general terminology so the statement can be applied in a variety of contexts.
When an object slides across a surface with more friction, it will come to a stop sooner than when it slides over a surface with less friction.

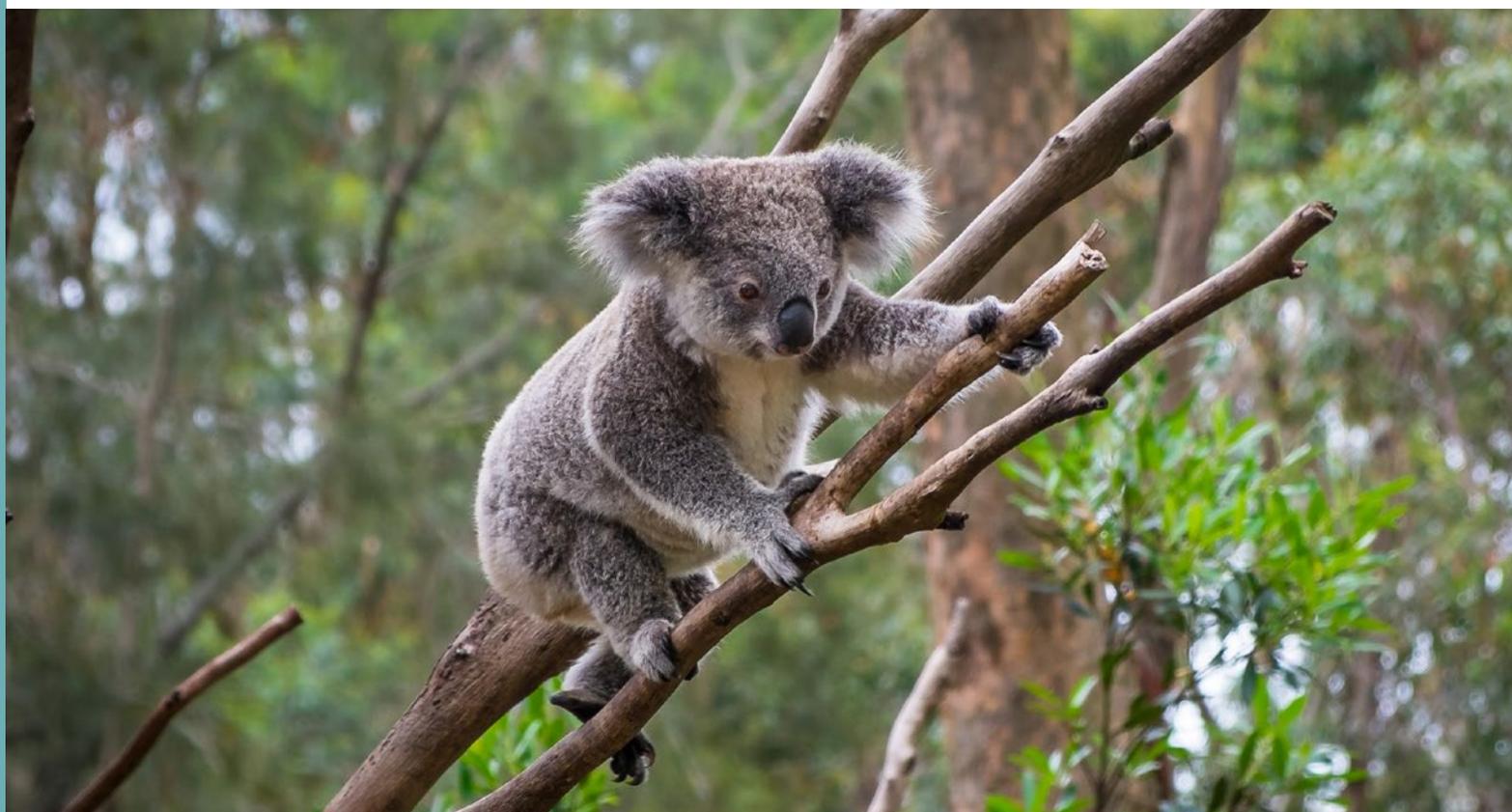
From the results, we analysed the trends and relationships in order to identify the finding and state the conclusion of the investigation. The term *car* was replaced with *object*, and instead of stating the specific surface used in the experiment, we generalised to the amount of friction – more or less. Table S2.6 provides some more examples of drawing conclusions.

Table S2.6: Converting investigation results into broader conclusions

Scientific finding	Conclusion
When carbon dioxide gas from a chemical reaction is captured in a balloon and then heated in a hot-water bath, the size of the balloon increases.	When the temperature of gas particles increases, the volume of the substance expands.
As the number of trees planted in eucalypt forests increases, the population of koalas also increases.	Revegetation efforts increase native animal populations by restoring natural habitats.
The more water a barrel contains, the greater the number of people required to push it 2 metres.	The greater the mass of an object, the more force is required to move it from a stationary position.

This does not mean that all our conclusions are correct. It is simply an opportunity to say what we know at that time and to investigate further.

Sometimes **data points** and conclusions do not follow the observed trend in a dataset or the expected outcome of an investigation. These are called outliers or **anomalies** and must be further analysed to determine whether the deviation is due to either an error in how the data was collected or to genuinely new discoveries. If they are mistakes or errors, they should not be averaged into the results. If it is unclear why there are anomalies, further investigations are required.





Evaluating

Evaluating investigations and conclusions is a bit like playing the role of a scientific inspector; it is about quality control! It involves carefully reviewing how the data was collected to determine whether the results are accurate and really do represent what they are supposed to measure. How close are the results to the true value? How valid is the investigation? Can the results be justified? Is there any conflicting evidence or unanswered questions? How can we make improvements? Work your way up the Learning Ladder to approach this skill effectively.

Step 1 I can identify errors and assumptions in an investigation

In any investigation, our aim is to collect data that is accurate and valid. In other words, we want our results to find the **true value** that answers the experimental question by conducting a **fair test**. It is up to us, the investigators, to identify sources of errors that lower the **accuracy** and validity of the results. Ask yourself the following questions to reveal problems with the investigation:

- 1 Was my experimental set-up or process different from the intended procedure?
- 2 Did I record any qualitative observations related to difficulties or assumptions in the method?
- 3 Were there any new variables identified during the investigation that I had not controlled?
- 4 Did anything unexpected occur during the investigation, including strange results?

If you answered 'YES' to any of the above questions, you have just revealed sources of errors. In most cases, errors are due to controlled variables that were not controlled properly.

Let's consider the investigation question:

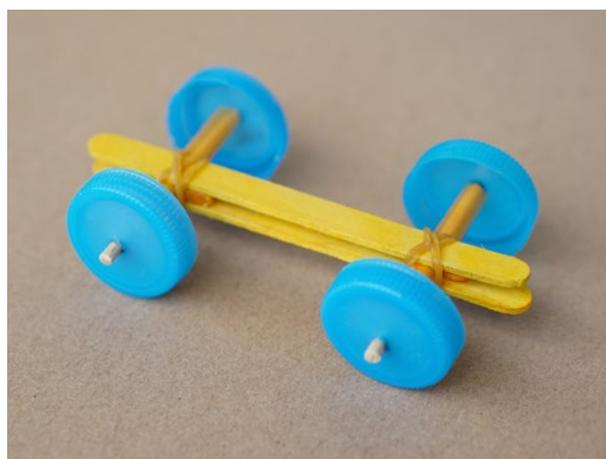
How does the type of wheel (bottle cap, CD, washer) affect the distance travelled by a model car?

Table S2.7 elaborates on how answering 'YES' to each question can lead to the identification of errors. Each of the errors identified reduces the accuracy and/or validity of the results.

Table S2.7: Identifying the sources of errors

Questions to reveal errors	Describing the scenario	Source of error
1 Did your experimental set-up or process differ from the intended procedure?	<i>The method required the ramp to be propped up on a printer box, but there was only one box. To save time, different things were used to prop up the ramp for each car. This method went against the intended procedure.</i>	<i>Different ramp angles were used for each car.</i>
2 Did you record any qualitative observations related to difficulties or assumptions in the method?	<i>The cars did not always move in a straight line, which caused variations in how the distance was recorded. If it went straight, the total path of the car was measured, but if it curved, the distance from the starting line to the stopping point was measured directly. This shows that assumptions were made about the path and distance the cars travelled.</i>	<i>The way the distance was measured was not consistent for all three cars.</i>
3 Were there any new variables identified during the investigation that were not controlled?	<i>The type of wheel was the independent variable for this investigation, but it is not clear whether the material type or the size of the wheel is responsible for the results.</i>	<i>The material AND size of the wheels differed, which means there is more than one independent variable.</i>
4 Did anything unexpected occur during the investigation, including strange results?	<i>During the third trial for the car with washer wheels, a gust of wind came through the classroom. Interestingly, the car in this trial went the furthest by far, as compared to the other two trials.</i>	<i>The surrounding environment was not kept constant for all trials, (e.g the gust of wind that passed through the classroom in one trial).</i>
	<i>For some trials, the student pushed the car down the ramp instead of letting it roll on its own as the method indicated.</i>	<i>The force applied to the cars was not consistent across all three trials.</i>

Figure S2.27: We can see that different-sized wheels were used in this experiment; therefore, this is a source of error in the results.



Step 2 I can describe different types of errors in an investigation method

There are different types of errors that you may encounter in an investigation. Being able to identify and describe the types of errors present will help you to understand how they have impacted on your data. Table S2.8 summarises the different types of errors you will be expected to recognise.

Table S2.8: Types of errors

Type of error	Description
Random	Unpredictable differences in how measurements are taken, resulting in a 'random' variation of values.
Systematic	A consistent difference in measurement from the true value. When a particular value is measured repeatedly, the error is the same.
Personal	Mistakes that can be avoided if the method is followed correctly. Rather than discussing personal errors in a report, the method should be repeated to eliminate mistakes.

Table S2.9 considers the sources of error identified in step 1 and determines their type.

Table S2.9: Types of sources of error identified in step 1

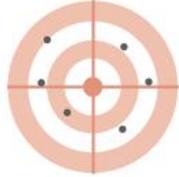
Source of error	Type of error	Supporting information
Different ramp angles were used for each car.	Systematic	<i>If two ramps had the standard angle but the ramp for the CD car had a higher angle, the CD car would experience more force down the ramp, leading to a greater distance travelled than if it had gone down the standard ramp. The additional distance travelled would be relatively the same for every trial for that car.</i>
The way the distance was measured was not consistent for all three cars.	Random	<i>The method did not specify how to measure the distance travelled; therefore, it may have been done differently across all cars and trials. There is no way to know how much or in what direction the values vary from the true values.</i>
The surrounding environment was not kept constant for all trials (e.g. the gust of wind that passed through the classroom in one trial).	Random	<i>External factors may have influenced the cars' performance down the ramp for better or worse, but there is no way to know the extent of the impact.</i>
The force applied to the cars was not consistent across all three trials due to some students pushing the car at the start.	Personal	<i>This mistake can be avoided if the method is followed correctly. If it is not possible to redo the investigation, this would be considered a random error as you have no way to know the impact of the mistake. Ideally, the trials where the cars were pushed should be eliminated from the data and redone.</i>

Step 3 I can use science-based explanations to support investigation findings

Once you understand the difference between various types of errors and their sources, the next step is to support the investigation findings with evidence-based explanations of how the errors affect your data. It is not enough simply to say that an error will reduce the accuracy or validity of results. This is assumed in step 1 of the Learning Ladder. At step 3, you are expected to discuss specifically HOW the error affects your investigation findings. Does it increase the experimental value? Why, and by how much? This is the evidence required to support your findings.

Random and systematic errors each have a known impact on the data, as Table S2.10 illustrates.

Table S2.10: Known impacts on data of random and systematic errors

Error type and impact	Elaboration
Random errors reduce precision  *Values are spread around the centre true value	<i>Each data value is not accurate; however, the average of all values is often close to the true value. Therefore, random errors do not necessarily affect the accuracy of an experiment, as long as there are enough trials to average out the error.</i>
Systematic errors reduce accuracy  *Values are close to each other but not to the true value	<i>Data values are precise but not accurate, because the collection of data is affected in a predictable and consistent way. For example, an uncalibrated scale used to measure mass might add 1 gram to all measurements.</i>
Personal errors can reduce precision and/or accuracy	<i>Mistakes can be random errors or systematic errors, depending on whether the impact on the data varies or is consistently predictable. Refer to step 2 for more information.</i>

To effectively support your findings with evidence-based explanations about the quality of your data, you must first determine the type of error present and its general impact, as outlined above. This is the first item on the checklist below.



CHECKLIST FOR SUPPORTING FINDINGS WITH EVIDENCE-BASED EXPLANATIONS

- Determines the type of error and its impact on the data; reduces precision and/or reduces accuracy
- Compares experimental values to the true values, where possible, referenced in scientific literature (see the 'Conducting scientific research' section on page 266)
- Uses descriptive words to describe the impact on data (higher, lower, heavier, stronger, shorter, etc.)
- Makes links between the quality of data and the accuracy and/or validity of the results

Use the checklist to ensure your explanation includes everything necessary for you to display your skills at step 3 of the Learning Ladder.

Let us now revisit a couple of the errors from the previous step to see how they can be explained with reference to the quality of data (see Table S2.11).

Table S2.11: Evidence-based explanations of possible sources of error

Source of error	Evidence-based explanations to support findings
Different ramp angles were used for each car (systematic).	The distance travelled for the CD car (higher angle ramp) is greater than it would have been on a standard ramp. This increases all values recorded for the CD car by the same amount, reducing the accuracy of the average of the trials for this car. This, in turn, reduces the validity of the results as we cannot be sure if the CD would have gone further than the other cars had it been done on a standard ramp.
The way the distance was measured was not consistent for all three cars (random).	As a result of inconsistent measuring, the precision of data values is reduced. There is no way to know how much or in what direction each value differs from the true values. Because there were three trials for each car, the average of all three trials is closer to the true value than a single data value on its own. Averaging trial values improves the quality of the data and, as a result, increases the accuracy of the results.

*The text colour coincides with the checklist items on the opposite page.

Please keep in mind that there may be several correct ways to use evidence-based explanations to support investigation findings. The more practice you have, and the more feedback you get from your teacher, the more comfortable you will become with using this skill.

Step 4 I can create evidence-based arguments to justify conclusions or evaluate claims

Now that you know how to support investigation findings with reference to errors and assumptions, the next step is to construct evidence-based arguments to discuss a variety of factors involved in first- and second-hand investigations. This includes things related to the quality of data collected, as outlined in step 3, such as how errors may have affected your investigation findings.

For help with writing an evidence-based scientific argument, see the ‘Scientific writing’ section on page 259. Now, combine your explanations from step 3 and/or your analysis of the impact of errors on your data, and construct your argument.

Step 5 I can evaluate conclusions and claims with reference to conflicting evidence and unanswered questions

It is important to be cautious when reading and utilising second-hand data and information. There are times when evidence within an investigation report or across multiple studies is conflicting. For example, one investigation might indicate that drinking a soft drink before you run a race will help you to run faster, while another might suggest that it slows you down. In situations like this, evaluating the claims can help you to verify which source is more or less accurate in its findings. Maybe the first investigation used faster runners, indicating that the variables may not have been properly controlled.

There are also sometimes unanswered questions that should be considered when evaluating conclusions and claims. For instance, what type of soft drink was used in the investigation: regular, sugar-free, caffeine-free? And was it opened right before the test? From a bottle or a can? If these things are not specified in the investigation report, they become questions that need to be answered before the claims can be properly evaluated.

If conflicting evidence and/or unanswered questions persist within and across investigation reports, a formal evaluation should make reference to these factors. Further research would be required before the conclusions or claims can be justified.

Use the checklist below to evaluate the conclusions and claims of an investigation.



CHECKLIST FOR EVALUATING CONCLUSIONS AND CLAIMS

- One variable was changed.
- One variable was measured.
- All other variables were properly controlled, without any assumptions.
- Any variables that were not well controlled are acknowledged and discussed in the investigation report.
- Any safety and/or ethical considerations have been considered.
- No other reliable sources present evidence that conflicts with the claims made.
- There are no unanswered questions related to the results that support the findings.

Ticking each of the items in the checklist does not guarantee that the conclusions or claims are fully justified. Nor do all items need to be ticked in order for a claim to be true. The checklist is just a guide to help us evaluate a variety of scientific claims by asking standard questions as a starting point. More questions can always be asked and further studies carried out to help us continue to contribute to the scientific body of knowledge in safe, thorough and ethical ways.

Communicating

Communicating is essential to science – scientists need to share the ideas they have and the findings they have discovered. When we communicate, we need to consider what we are trying to say, and who we are trying to say it to. This allows us to present our ideas and findings using specific methods and language targeted to our particular audience.

Step 1 I can identify scientific terminology used to communicate information

In science, specific scientific terminology is used to communicate findings or ideas to other scientists. Scientific terminology can help us to describe specific features or qualities, and allow us to communicate information from a first-hand investigation.

To recognise scientific terminology, you need to consider the following:

- Do the words used provide information about the science behind this idea or concept?
- Are the words specific and used correctly in context?

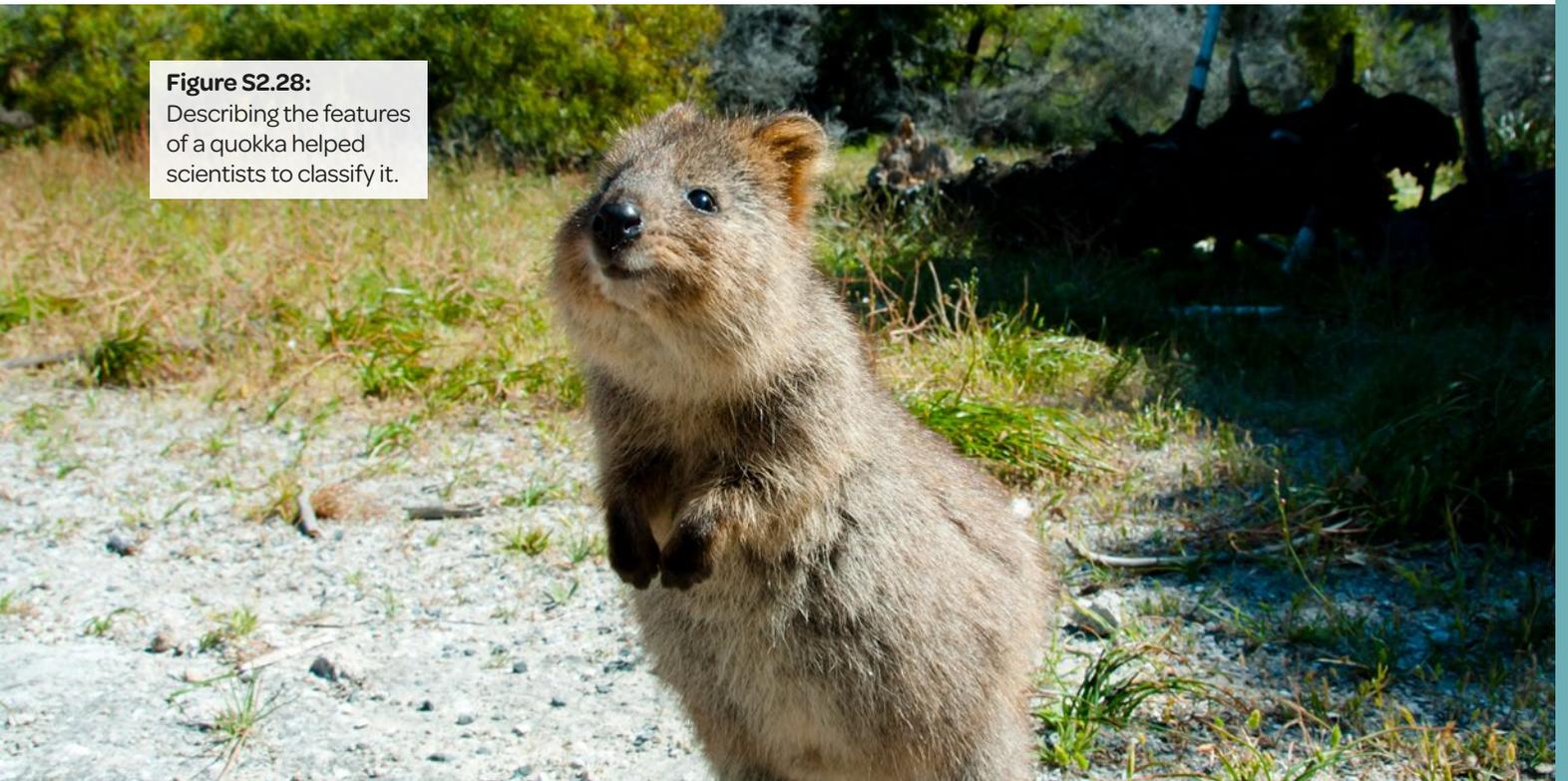
For example, if we want to identify scientific terminology related to the quokka, we can study the following passage:

The quokka (Setonix brachyurus) is a mammal that is part of the same family as the kangaroo and the wallaby, and part of kingdom Animalia. Quokkas are herbivores, living off native shrubs and grasses on Rottnest Island in Western Australia. Quokkas are currently listed as a 'vulnerable' species, because they are eaten by predators, usually introduced species such as cats.

The passage describes part of the classification of the quokka, as well as its diet, habitat and predators. Specific classification and biology terms are used, and they correctly describe the quokka from a scientific perspective. This allows us to identify that the passage contains specific scientific terminology.

Figure S2.28:

Describing the features of a quokka helped scientists to classify it.



Step 2 I can select appropriate formats to communicate ideas and findings

You can communicate your scientific findings in many different ways. To decide on a suitable method of communication, ask the following questions:

- What information do I have?
- What do I want to communicate to the audience?
- What format will display this information most clearly?

Table S2.12 shows some examples of how to apply these questions to make your decision.

Table S2.12: Choosing formats for scientific communication

Information	Communication goal	Format
Data from a first-hand investigation	What I found out while investigating a scientific question	Scientific table or graph
A complete first-hand investigation	How I did the investigation and what the results of the investigation were	Scientific report
What causes an eclipse	How the movement of the Sun, Earth and Moon cause an eclipse	Scientific poster with text and diagrams
Water movement	How water moves through the different stages of the water cycle	Scientific diagram with labels
Bacteria structure	What a bacteria cell looks like and contains	Scientific model

▼ **Figure S2.29:** A scientific model of an animal cell showing its features



Step 3 I can prepare a variety of representations to communicate ideas and findings

After selecting a method of communication, and a format to present it, you can then look at how to construct a presentation. When considering how to present scientific information in a chosen format, you can ask the following questions:

- What is the main point I want to get across?
- What information do I need to include in this format?
- What is the best way to present this information in my chosen format?

Once you have answered these questions, you can start to put your information into your selected format. Make sure you are using correct scientific terminology and information relating to your topic. More detailed examples of how to construct each type of presentation can be found in the 'Scientific writing' section on page 259.

Step 4 I can use digital technologies to organise and communicate data and information

Once you have selected an appropriate way to communicate your information, it is important to be able to represent any data you have digitally. Using digital technologies means that information can be presented neatly and succinctly, so that it is easy for audiences to understand. Table S2.13 provides a range of examples.

Table S2.13: Digital presentation formats

Information	Presentation format	Example communication presentation method
Data from a first-hand investigation	Scientific table or graph	Google Sheets or Microsoft Excel
A complete first-hand investigation	Scientific report	Google document or Microsoft Word document, with typed information
What causes an earthquake	Scientific poster with text and diagrams	Canva or slides to visually present information
Water movement	Scientific diagrams with labels	Canva, slides or Lucidchart software to create a diagram with labels
Bacteria structure	Scientific model	Canva or Lucidchart software to create two-dimensional models



◀ **Figure S2.30:** Digital technologies help us to neatly lay out information ready for presenting.

Step 5 I can communicate scientific findings and arguments for specific purposes to specific audiences

Now that you can determine appropriate communication formats, you should select information and text that matches the audience you are trying to communicate with. To help you figure out *how* to tailor your communication, consider the:

- age of your audience
- knowledge level of your audience
- idea or scientific principle you want to communicate
- best way to tell your audience about this principle.

Table S2.14 shows how the same information can be presented to two different audiences.

Table S2.14: Tailoring your message for different audiences

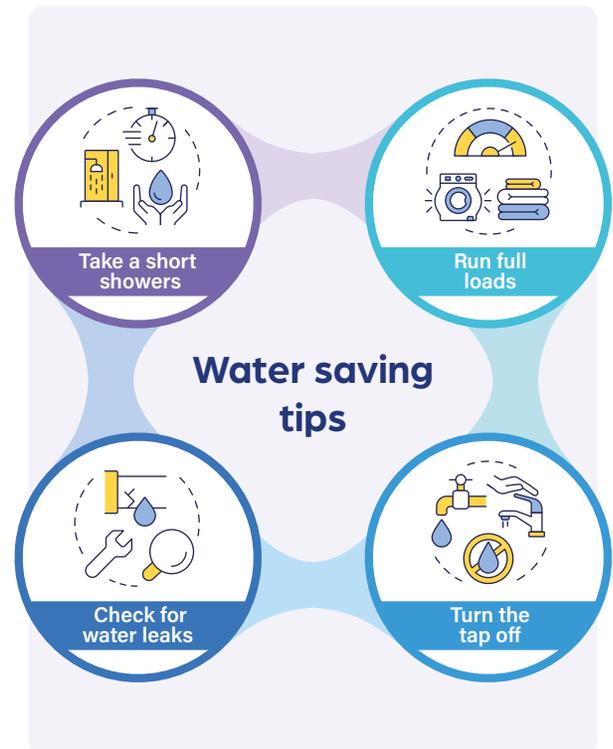
Age	Knowledge level	Idea	Communication
Eight-year-old children	Very limited	Water as a resource	Summarise the water cycle and encourage household water-saving measures on a poster.
Adults	High – environmental scientists	Water as a resource	Present research on ideas to prevent surface evaporation from lakes and dams as an article or oral presentation.

We can then create a communication format for each audience. For the eight-year-olds, we could include the following text on a simple poster.

In the water cycle, rain falls and then runs off into storage areas like dams and lakes. We use some of this water in our homes. To help us use less water, we can take shorter showers or shallow baths, and turn off taps while cleaning our teeth. These actions mean every household uses less water overall, and this is also known as using water sustainably.

The adult scientists would expect more sophisticated language, and the information could be displayed using specific diagrams and figures.

When water that has precipitated runs off into storage areas such as dams and lakes, it is subject to surface evaporation, reducing the amount available for household consumption. Placing products such as evaporation-reducing shade balls on the surfaces of these areas will assist in minimising surface evaporation, reducing water loss and increasing availability for household usage, even in times of drought.



▲ **Figure S2.31:** A poster showing sustainable water usage in the home would be a suitable communication method to share ideas with younger audiences who have little scientific knowledge.

S3

Scientific writing

'Scientific writing' means applying your writing skills to your science studies to help you develop your understanding and communicate what you have learnt.

Key term

plagiarise: to copy someone else's work and present it as your own

Figure S3.1: Scientific writing is fundamental to science communication.



Table S3.1: Investigation report sections matched to their science inquiry skills

Section	Focused skill	Embedded throughout
Title	Questioning and predicting	Communicating
Introduction <ul style="list-style-type: none"> ▪ Background ▪ Aim ▪ Hypothesis 	Questioning and predicting	
Risk assessment	Planning and conducting	
Materials	Planning and conducting	
Method	Planning and conducting	
Results	Processing, modelling and analysing	
Discussion	Processing, modelling and analysing Evaluating	
Conclusion	Evaluating	
References	Evaluating	

Writing investigation reports

Writing a clear and concise report after your investigation is complete will help other people to understand your work. Table S3.1 provides an overview of the sections that are often included in a standard investigation report, as well as the science inquiry skill used in each section.

Your investigation reports should typically have a similar structure to the one shown below.

The title is clear and uses plain language. Many scientists write their title as a research question.

Set the scene. If there is scientific information or context for the investigation, summarise it here.

The background often leads into the objective of the investigation. Use your research question to write the aim starting with a verb, such as: 'To investigate ...'

If your investigation is an experiment, you should predict what you think will happen based on scientific theory. A good hypothesis will include the independent variable and the predicted effect on the dependent variable.

List all materials and equipment with amounts and sizes as simple bullet points.

The method shows how the investigation was conducted. Number the steps, and write in the past tense and in the third person.

Methods should be written like a recipe – simple, clear and detailed.

How does the amount of direct sunlight affect plant growth?

Introduction

Plants require sunlight to produce their food using photosynthesis. Some plants get direct sunlight, while others get indirect sunlight. It would be interesting to know how different plants are affected by different amounts of sunlight, to help us make decisions about where to put garden beds for certain types of plants.

Aim

To investigate whether the amount of direct sunlight affects growth of a certain species of plant.

Hypothesis

If a plant is placed in direct sunlight, then it will grow more than a plant in indirect or no light, because plants require sunlight to produce food required for growth.

Materials

- 3 plants of the same species and of similar size
- 250 mL beaker

Method

- 1 Each plant was labelled 1, 2 or 3 and measured to obtain a starting height for each one. The heights were recorded in a simple table.
- 2 Plant 1 was placed in a dark cupboard.
- 3 Plant 2 was placed near a window where it could receive indirect sunlight.
- 4 Plant 3 was placed outside in direct sunlight but sheltered from rain.
- 5 The heights of the plants were measured every week for three weeks and the growth was recorded in the results table.
- 6 The plants were watered the same amount every three days.

Results

Table 1: Effect of sunlight on plant growth

Plant environment	Initial height (mm)	Growth after 1 week (mm)	Growth after 2 weeks (mm)	Growth after 3 weeks (mm)
Plant 1: no sunlight	181	0	-1	-3
Plant 2: indirect sunlight	175	1	2	4
Plant 3: direct sunlight	178	2	3	5

Discussion

As the results in Table 1 show, the plant that had the most growth was the plant in direct sunlight (Plant 3). The plant in direct sunlight had the highest growth, with 2 mm after the first week, 3 mm after the second week and 5 mm after the third week, compared to the plant in no sunlight (Plant 1), which had no growth, then shrank and lost growth in weeks 2 and 3. The results make sense because sunlight is crucial in photosynthesis – the process by which plants transform sunlight into usable energy.

One source of error is that two of the plants were inside, and one was outside, which may have had an impact on growth. The method could be improved by requiring all plants to be outside, each with a different amount of shade coverage. There may have also been some errors to do with accurately measuring the plants. The method could be improved by including photos of the plants against the same ruler backdrop, to confirm the accuracy of measurements.

Conclusion

The results of this investigation show that the amount of direct sunlight does impact on the growth of this species of plant. The investigation supported the hypothesis that if this species of plant is put in direct sunlight, it will grow more than a plant of that species in indirect or no light. This is due to more sunlight being available for photosynthesis, which is how plants grow.

References

BBC, 2019, 'Photosynthesis', BBC Bitesize Articles, accessed 10 January 2024, [mea.digital/gsvic8_9_1](https://www.bbc.com/primary/science/revision/2019/01/20190110_photosynthesis).

Include recorded data such as the results table. Include any visual elements, such as photos or graphs, here.

Use the discussion to analyse the results and identify a key finding. Evaluate the method to identify the quality and limitations of the data.

Start by summarising the data, using amounts in your table. Identify any trends or patterns that could lead to your key finding. Link your finding to your scientific understandings.

Identify any potential errors here and suggest improvements to try to control them.

Conclude the report by responding to the aim. Mention whether the results supported or refuted your hypothesis. Do not present any new information.

The conclusion can also be the closing paragraph of the discussion.

References show the source of any information you used that was not your own, including for the background.

Presenting scientific information

The ability to choose and create an appropriate presentation format allows you to transform complex ideas into engaging concepts and to share your discoveries in ways that will best reach your audience. Presenting scientific information effectively is a powerful tool that can help shape the future of science.

Posters

The purpose of a scientific poster is to communicate information on a particular topic or to display the findings of an investigation in a quick and engaging way. When information is shared on a poster, it should be easy for people to see the main idea as they are walking past. A display of scientific posters might include dozens of posters lined up, one after another. This is why it is important for your main finding to be the central focus.

A poster includes the same sections as an investigation report. However, each section includes only the most important information. Anyone who wants to learn more about the investigation details can read the full report. Figure S3.2 shows the basic framework for a scientific poster.

Figure S3.2: ▶
A simple framework for the structure of a scientific poster

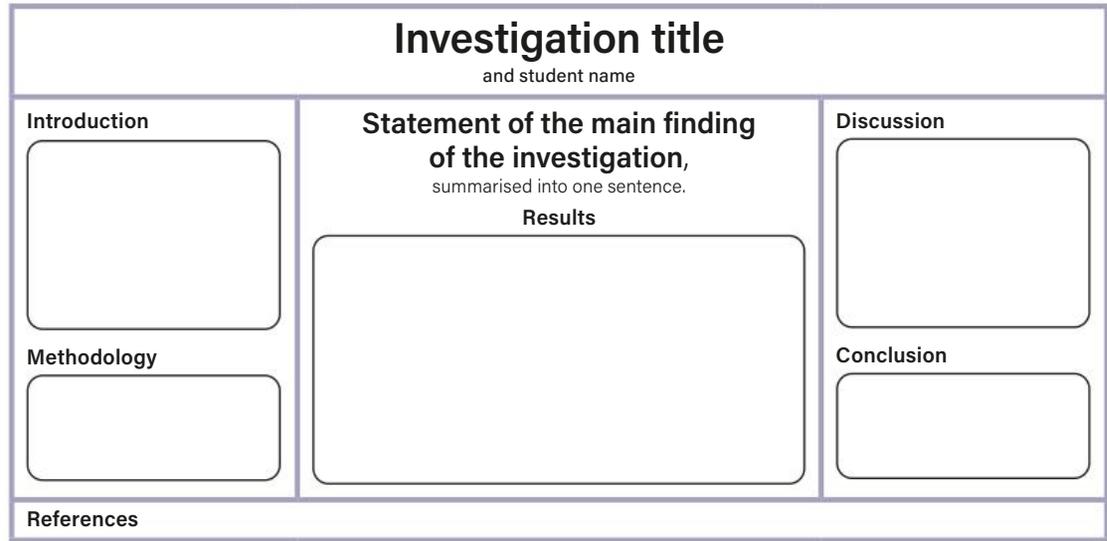


Figure S3.3:
A simple scientific poster

Figure S3.3 gives an example of how we might present, in poster form, the findings from an investigation report on plants and sunlight. We could add visual interest by adding photos or illustrations of the plants.

How does the amount of direct sunlight affect plant growth?

Introduction

Plants require sunlight to produce their food using photosynthesis. This investigation aims to explore how the amount of sunlight affects plant growth. It is hypothesised that 'If a plant is placed in direct sunlight, then it will grow more than a plant in indirect or no light.'

Materials & method

Three plants were placed in different locations: in a dark cupboard, near a window with indirect sunlight, and outside in direct sunlight but sheltered from rain. All the plants were watered the same. Plant height was measured every week for three weeks.

Plants with direct sunlight grow more than plants of the same species with indirect or no light.

Results data

Table 1: Effect of sunlight on plant growth

Plant environment	Initial height (mm)	Growth after 1 week (mm)	Growth after 2 weeks (mm)	Growth after 3 weeks (mm)
Plant 1: no sunlight	181	0	-1	-3
Plant 2: indirect sunlight	175	1	2	4
Plant 3: direct sunlight	178	2	3	5



Discussion

The plant that had the most growth (5 mm) was the plant in direct sunlight. The plant in no sunlight had no growth in week 1, then shrank in weeks 2 and 3. The results make sense because sunlight is crucial in the process by which plants transform sunlight into usable energy – photosynthesis.

One source of error is that two of the plants were inside, and one was outside, which may have had an impact on growth. The method could be improved by requiring all plants to be outside.

Conclusion

The investigation supported the hypothesis that if this species of plant is put in direct sunlight, it will grow more than a plant of that species in indirect or no light.

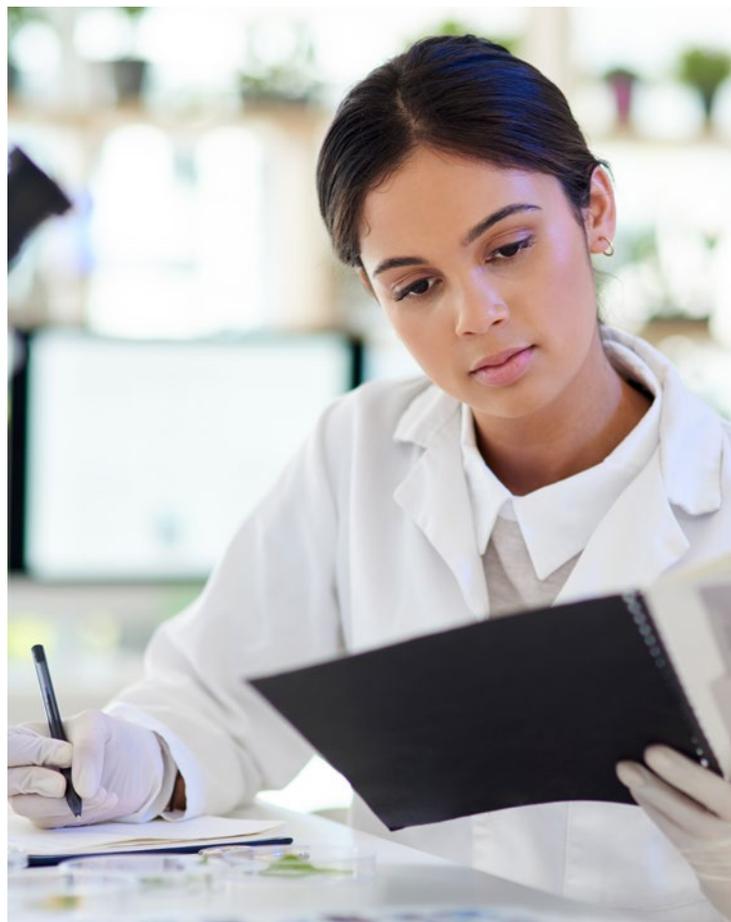
Reference: BBC, 2019, 'Photosynthesis', BBC Bitesize Articles, accessed 10 January 2024, [mea.digital/gsvic8_9_1](https://www.bbc.com/bitesize/guides/zea9w9/1/revision/1).

Articles

The purpose of a scientific article is to communicate the findings of an investigation or to summarise research into secondary sources. A scientific article is divided into specific sections, each with a purpose to communicate specific information relating to the scientific concept being studied.

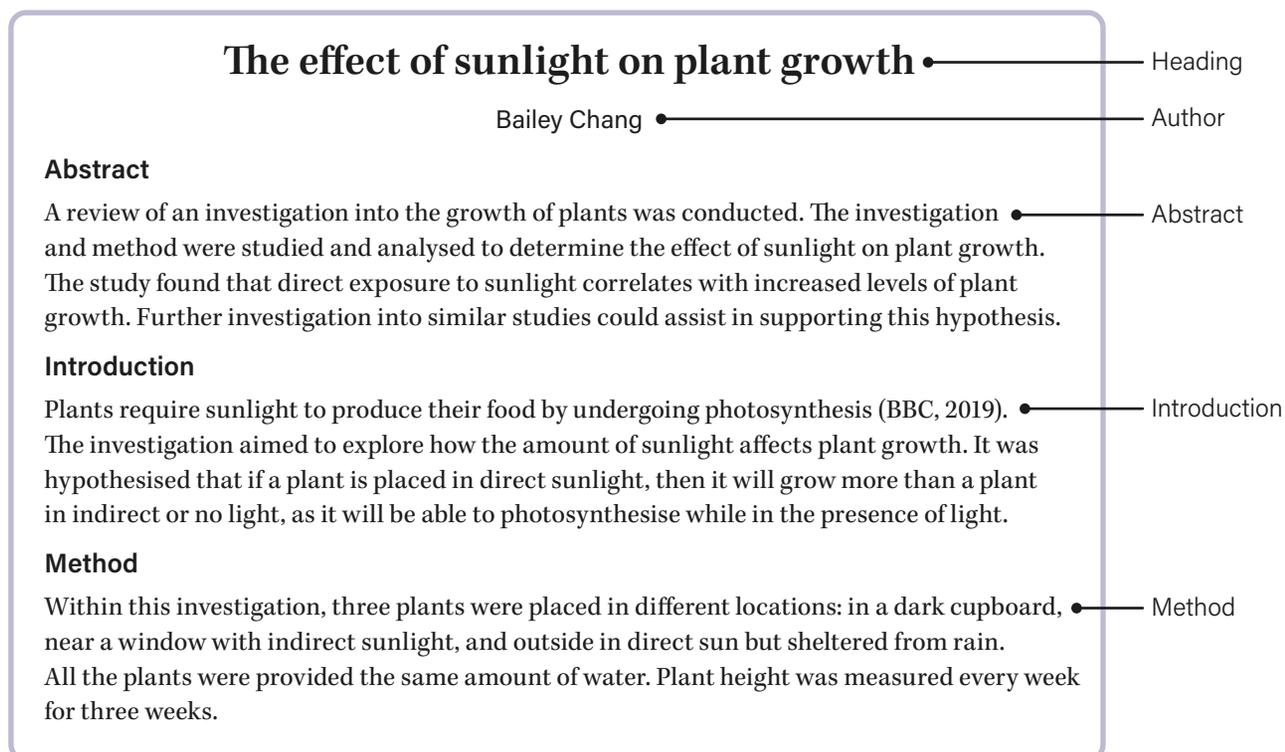
- 1 Heading – a relevant title that is a statement of what the article is about
- 2 Author – the name of the person writing the article
- 3 Abstract – a summary of what was done or what was found in the study
- 4 Introduction – some research on and background to the topic, linked to a hypothesis
- 5 Method – the methods scientists used to investigate the topic
- 6 Results – the results found about the topic
- 7 Discussion – a detailed analysis of the results, linked to the background
- 8 References – a list of your sources. See the ‘Referencing’ section on page 268 for more information.

Figure S3.5 provides an example framework for a science article.



▲ **Figure S3.4:** High-quality scientific articles can be reviewed by other scientists and published in scientific journals.

▼ **Figure S3.5:** The structure of a science article on plant growth



Results

● **Results**

It was found that sunlight has a direct impact on plant growth. Table 1 shows the amount of plant growth in different levels of sunlight.

Table 1: Effect of sunlight on plant growth

Plant environment	Initial height (mm)	Growth after 1 week (mm)	Growth after 2 weeks (mm)	Growth after 3 weeks (mm)
Plant 1: no sunlight	181	0	-1	-3
Plant 2: indirect sunlight	175	1	2	4
Plant 3: direct sunlight	178	2	3	5

Discussion

● **Discussion**

The results show that sunlight exposure had a direct impact on plant growth levels. It was found that the plant in direct sunlight had the most growth (5 mm). The plant in no sunlight had no growth in week 1, then shrank in weeks 2 and 3. The results make sense because sunlight is crucial in the process by which plants transform sunlight into usable energy – photosynthesis.

One source of error is that two of the plants were inside, and one was outside, which may have had an impact on growth. The method could be improved by requiring all plants to be outside. This would make the investigation valid.

References

● **References**

BBC, 2019, 'Photosynthesis', BBC Bitesize Articles, accessed 10 January 2024, [mea.digital/gsvic8_9_1](https://www.bbc.com/1/health/science/2019/01/20190110-photosynthesis).

Presentations

The purpose of a scientific presentation is to communicate the findings of an investigation or article quickly and concisely. You need to summarise the key methods and findings clearly, as your audience may view several presentations in one sitting.

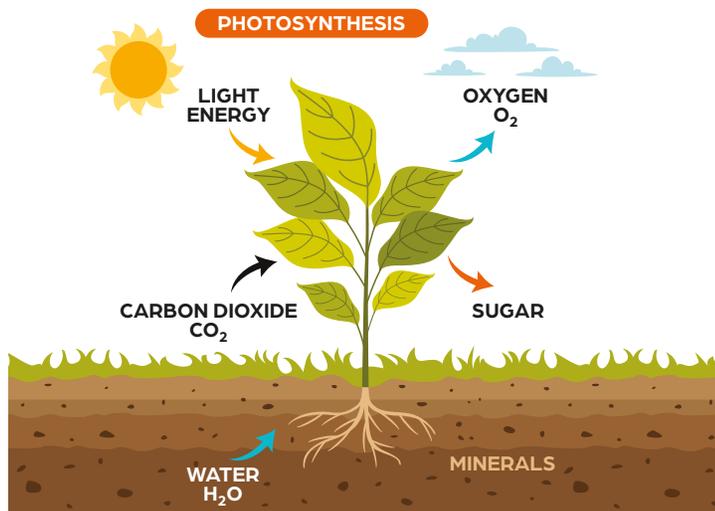
Include the same sections that you would in a scientific article to provide your audience with an overview of the concepts. Those who are interested can then read the full report.

To create a clear oral presentation, use the following tips:

- Pick a theme and stick with it.
- Use carefully selected images that help you to make your point.
- Ensure the summary on each slide is large enough to be read from the back of the room.
- If you use slide transitions, only use one type for the whole presentation as too many can be distracting.

Introduction

Plants require sunlight to produce their food using photosynthesis. This investigation aims to explore how the amount of sunlight affects plant growth. It is hypothesised that if a plant is placed in direct sunlight, then it will grow more than a plant in indirect or no light.



◀ **Figure S3.6:** An example of a slide layout for a scientific presentation

Models

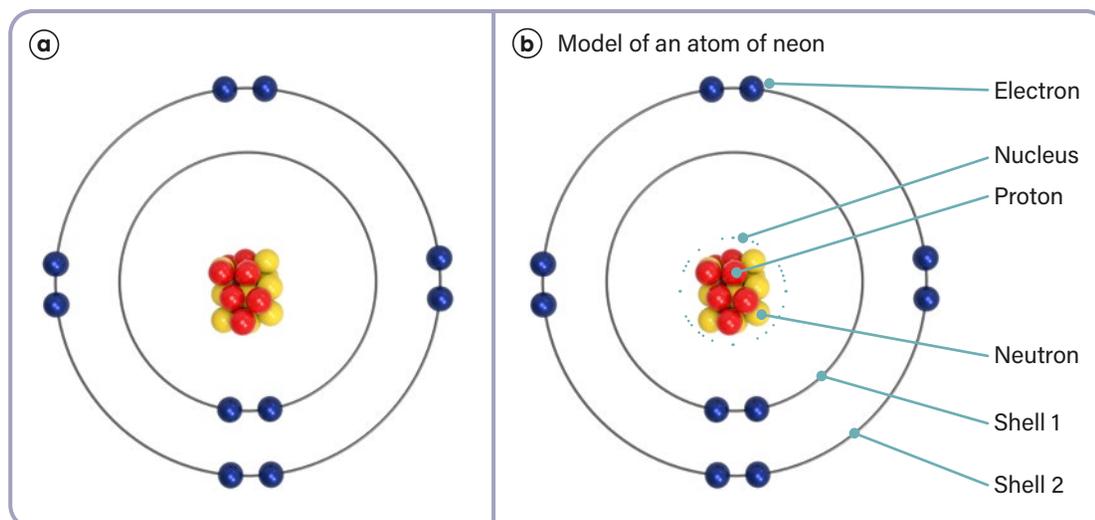
The purpose of a scientific model is to provide a representation of a scientific concept that could be difficult to see or understand. Scientific models can show microscopic or large-scale ideas that are impossible to view with the naked eye, or they can help us to visualise the parts and functions of something; for example, a model of how the human eye works.

To construct a good scientific model, use the following criteria:

- Does this model contain all of the relevant components of the concept it is showing?
- Is each section of the model clearly labelled?
- Can the model be easily interacted with (visually or physically) by the audience?

Figure S3.7a aims to inform the audience about the structure of a specific atom.

However, it is missing specific labels. To improve the information it communicates and make it a better scientific model, labels should be added. Figure S3.7b is appropriate as it also includes labels of the atom and its structures and components.



▲ **Figure S3.7:** (a) A model of an atom of neon that is missing labels; (b) an improved model of an atom of neon including labels

Conducting scientific research

CRAAP

When conducting scientific research, we need to confirm that the information is valid. Even if a source looks credible on the surface, it may not have valid information. One way that we can check this is by using the CRAAP test.

Currency: is the information on the source up to date? Was it recently published (or published in a time relevant to the information)?

Relevance: does the information answer the question I am asking? Is it written in a way that I can understand?

Authority: does the author of the text have experience in this branch of study? Do they have appropriate qualifications to be giving out information on the topic?

Accuracy: where is the information from? Can I find similar information across multiple sources? Is there evidence supporting the information?

Purpose: why is this particular author or company publishing this information? Are they unbiased or are they trying to sell a particular viewpoint? Is the information fact or opinion?

Source: Meriam Library, California State University, Chico.

A secondary source of information must meet *all* of these criteria to be considered a valid source. If the source meets the criteria, use it to support your scientific writing. For example, when looking at the question ‘How is water used in Australia?’, we can analyse the two sources of information about water set out in Table S3.2. The table shows us that the first source meets all of the CRAAP criteria, making it valid, while the second source only meets two criteria and should be disregarded.

Table S3.2: Evaluating research sources for the topic of water

Source	Source 1: 'Water Use in Australia, 2024–25'	Pass?	Source 2: 'My Opinion on Water Use in New Zealand'	Pass?
Currency	Updated recently, with the date of last update clearly stated e.g. <i>last updated: 7 June 2025</i> – current	<input checked="" type="checkbox"/>	Updated recently, with the date of last update clearly stated e.g. <i>last updated: 13 June 2025</i> – current	<input checked="" type="checkbox"/>
Relevance	Provides information on the distribution and use of water in Australia – highly relevant	<input checked="" type="checkbox"/>	Provides information on water use, but not in Australia – related, but not relevant for our research question	<input checked="" type="checkbox"/>
Authority	Reputable scientific organisations or research bodies that state clearly their qualifications and methods e.g. <i>Geoscience Australia</i> – a government department focused on water research – good authority	<input checked="" type="checkbox"/>	No listed qualifications, or qualifications are from organisations that don't exist; the author might be an expert in a different field but isn't qualified to be considered an expert on water	<input checked="" type="checkbox"/>
Accuracy	Similar information can be found across multiple other reputable sources and is supported by evidence	<input checked="" type="checkbox"/>	Very few other sources include similar information; claims are not supported by evidence or are rejected by other experts in the field	<input checked="" type="checkbox"/>
Purpose	To educate Australians on where water is and how it is used, using current peer-reviewed scientific research	<input checked="" type="checkbox"/>	To share the opinion on water use of one person who is not an expert in the field	<input checked="" type="checkbox"/>

Types of information

When conducting research for investigations and articles, it is important to remember to include a variety of primary and secondary sources.

Primary sources are original, or first-hand, material and can include:

- letters or diaries
- photos
- research data
- laboratory notes
- data collected during first-hand investigations.

Secondary sources are materials that evaluate primary sources. These include:

- scientific reports
- journal articles.

There are also *tertiary sources* of information, which include both primary and secondary sources. Tertiary sources include:

- textbooks and encyclopaedias
- general-knowledge websites (make sure the authors are trusted and the information is current).

Some sources of information are considered *non-scientific*. You should not include these in your reports or articles. These include:

- your personal stories – back up your information with evidence!
- blogs or articles that are not based in fact
- personal opinions.

A well-constructed scientific report or article will include a combination of sources.

This shows that you have researched widely to ensure that you include valid and trusted information to inform your audience.

Researching information

When researching a scientific topic, sources include:

- textbooks, books, magazines and journals available from a library or online collection
- search engines such as Google; however, do not just use the information that pops up initially – visit the sites listed and ensure they pass the CRAAP test
- specific search sites such as Google Scholar, which will contain scientific journal articles relating to your topic.

When searching for information, remember:

- 1 Go to sources that contain valid information – check each one against the CRAAP test.
- 2 Choose three or four key words about your topic and use them when entering search terms into Google or Google Scholar; this should increase the number of relevant sites and articles that appear.
- 3 Save a copy of the URL (web address) for each website you use, and note down the details or take photos of every textbook or physical source you use. You will need this information when referencing your work at the end of your writing.

Figure S3.8:

There are many places to access valid sources of information. All sources of information should be referenced and cited in your written work.



Referencing

When researching and writing scientific material, you must acknowledge the sources of information you use. This is known as referencing. Referencing shows the audience that your information is supported by research, and that you have been careful not to **plagiarise**, or copy, the work of others. At the end of your report or article, you present the details of all your sources in a reference list.

A reference list should be in alphabetical order and follow a specific format. The most commonly used format in Australia is 'author–date'. Write each entry as follows:

- 1 surname of author(s) and first initial (or an organisation's name)
- 2 year the book or article was published
- 3 book title in *italics* or underlined; or article title in quote marks, with details of the journal
- 4 the title of the web page or the name of the publisher of the book
- 5 for digital content, the date you accessed it and the URL.

For example, below are references for a web article and a journal article.

BBC, 2024, 'Photosynthesis', BBC Bitesize Articles, accessed 9 February 2025, <https://www.bbc.co.uk/bitesize/articles/zn4sv9q>.

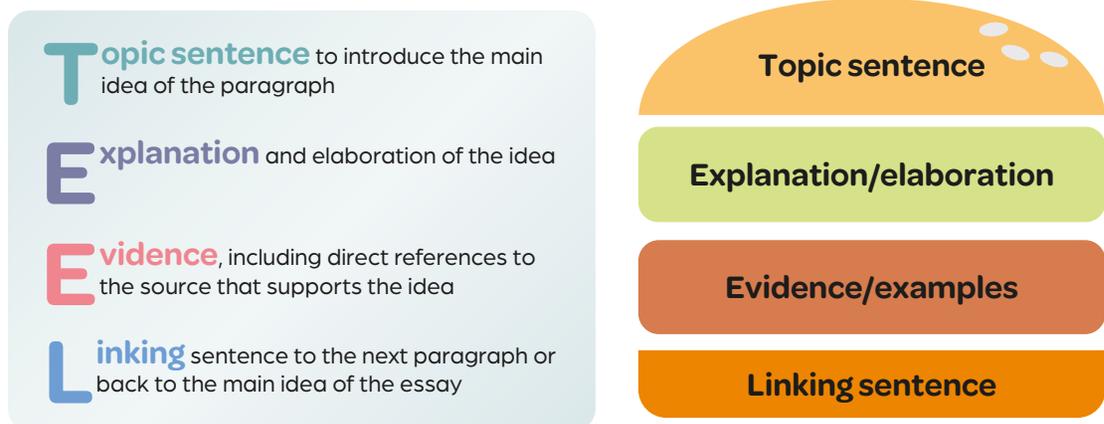
Hilty J, Muller B, Pantin F and Leuzinger S, 2021, 'Plant Growth: The what, the how and the why', *New Phytologist*, Volume 232, Issue 1, accessed 9 February 2025, <https://nph.onlinelibrary.wiley.com/doi/full/10.1111/nph.17610>.

Writing evidence-based essays

As part of your science studies, you will be required to write essays. Your essays must be supported by evidence. This type of scientific writing is usually informative or argumentative. In either case, you will need to structure your essay. One way to do this is to write an essay with five or more paragraphs or sections, consisting of:

- an introduction paragraph
- three or more body paragraphs
- a concluding paragraph.

Each body paragraph should follow the TEEL approach. The TEEL acronym reminds you of what to include in each paragraph of your essay:



▲ **Figure S3.9:** Each TEEL paragraph should build on the topic and link to the next idea or the essay as a whole.

Writing an informative essay

Informative scientific essays communicate scientific facts and ideas with a neutral tone, and cover all aspects of a topic. These essays are sometimes called research papers because they summarise multiple sources of research available on a particular topic, without including any opinions or personal narrative. There are many ways to structure an informative essay, such as the TEEL approach.

Writing a scientific argument

A scientific argument presents a position on a particular topic. Instead of all aspects of the research being communicated evenly, the research is evaluated and used by the writer to form a position.

Before you begin writing your argument, you will need to develop an evidence base by conducting research on the topic and evaluating each source. This will help you to choose your position.

For example, if the topic is nuclear power, you should find multiple sources that discuss positive and negative aspects of nuclear energy. Read each research piece carefully and critically. Review and evaluate each source by asking the following questions:

- Is this piece of evidence relevant?
- Is this piece of evidence written by a reputable person or group? (If not, it still may be useful as you could use it to criticise the opposing position.)
- What position does it take?
- Is it valid in taking this position?
- If it is not valid, what are the problems with it?

Use the answers to these questions to decide which position you intend to argue scientifically.

Finally, once you have established your position, you need to write your argument. You can follow the standard essay structure, using five or more paragraphs and the TEEL approach for each paragraph. Usually, each of your body paragraphs should provide a new reason why your position is valid.

Key terms

chemical formula: an expression of the elements that make up a chemical compound, usually presented as a ratio using letters and numbers; for example, H_2O

conversion factor: a number used to change one unit of measurement to another

density: how heavy something is for its size; mass divided by volume

equation: a mathematical statement that shows that two things are equal; for example, $2x + 6 = 14$ is an equation that needs to be solved so that $2x + 6$ does actually equal 14

exponent: the superscript value to the right of a number that says how many times to use the number in a multiplication; for example, when we write 10^3 , '3' is the exponent. It means we need to multiply 10 by itself 3 times

mathematical formula: a rule or principle that helps you to find the answer to a question or understand the relationship between variables

mean: a measure of centre (an average) calculated by adding all the numbers together and dividing by how many numbers there are

median: the middle number in a set of numbers when they are arranged in order

mode: the number that appears most frequently in a set of numbers

power: the end product obtained by multiplying a quantity by itself one or more times; for example, 2 to the *power* of 3 is $2 \times 2 \times 2$, which is 8, so the *power* of 2^3 is 8

range: in a set of numbers, a measure of spread between the highest number and the lowest number

ratio: a way of comparing like quantities without units

scale factor: the ratio between corresponding measurements of an object and a copy of that object

scientific notation: a way to write very large or very small numbers in a simple form

subscript: a letter or number written slightly below and to one side of another; for example, '2' in H_2O

superscript: a letter or number written slightly above and to one side of another; for example, '2' in 8^2

Understanding and applying basic mathematical concepts is essential for engaging with science effectively. It involves using mathematics to interpret and analyse scientific information, enhancing your comprehension of the scientific ideas you encounter in your studies and daily life.

Figure S4.1: In September 1999, NASA's *Mars Climate Orbiter* spacecraft was destroyed as it entered Mars' atmosphere. A conversion error meant the computer software controlling the probe used SI units, but was reading data in non-SI units. Instead of orbiting at 226 km above the surface, the probe descended too low, to just 57 km!



Units of measurement and converting

When we come across numbers in science, we need to identify:

- what the number is measuring
- the symbol used to represent the measurement
- what unit the number is measured in.

For example, you read that a ball takes 10 seconds to roll down a ramp, and you identify that:

- *time* is the measurement
- the symbol used is *t*
- the unit of measurement used is seconds.

In science, we use an international standard system of units for all types of measurements. These are called 'SI units'. We use some of these units every day, such as using metres to measure distance or minutes to measure time, but some others are only used in advanced science and maths. For example, in this book we use the common unit degrees Celsius ($^{\circ}\text{C}$) for temperature rather than the SI unit of kelvin (K).

Some numbers do not have units. If you swim two laps of a pool, the length can be measured in metres, but the number of laps will just be '2' with no units because it is a general quantity.

Table S4.1 shows measurements you will come across in this text, their symbol and unit.

Table S4.1: Some common measurements, symbols and units

Measurement	Symbol	Commonly used unit at this level
Length or distance	<i>D</i>	metre (m)*
Time	<i>t</i>	second (s)*
Speed or velocity	<i>v</i>	metres per second (m/s)*
Mass	<i>m</i>	gram (g), kilogram (kg)*
Volume	<i>V</i>	millilitre (mL)
Concentration	<i>g</i>	grams per litre (g/L)
Density	<i>d</i>	grams per millilitre (g/mL)
Temperature	<i>T</i>	degrees Celsius ($^{\circ}\text{C}$)
Force	<i>F</i>	newton (N)*
Energy	<i>E</i>	joule (J)*
Number of ...	<i>N</i>	no units

*SI unit

Tip 1: **Capitalisation matters.** Notice that *D* is the symbol for distance, while *d* is the symbol for density. If you mix up the lower and upper cases, it will change the meaning.

Tip 2: **Symbols are not the same as units.** Notice that *m* in *italics* is the symbol for 'mass', while 'm' in regular text is the unit for metres. Symbols are used to represent variables in an equation, while the unit tells us *how* the variable is measured. You should be able to distinguish between symbols and units.

Converting between units

Sometimes you will need to change measurements from one kind of unit to another. You can do this if you know the **conversion factor**. For example, if you are converting minutes into seconds, the conversion factor is 60 seconds (60 s), which is the number of seconds in a minute. At other times, you may need to look up the conversion factor. For example, on Earth a kilogram is about the same as 9.8 newtons, so the conversion factor from kilograms to newtons is 9.8. Once you know the conversion factor, you then need to multiply or divide.

If the new unit you are converting to is larger, you must divide by the conversion factor.

If the new unit is smaller, then you multiply by the conversion factor.

For example, converting minutes to seconds is from a larger unit to a smaller unit, so you multiply by 60. Converting from seconds to minutes is from a smaller to a larger unit, so divide by 60. Worked example 1 shows more examples of conversions.

Worked example 1: Converting between units

- 1 Convert 2.5 kilometres to metres.

Answer: $2.5 \times 1000 = 2500 \text{ m}$

- There are 1000 metres in a kilometre, so the conversion factor is 1000.
- This conversion is from a big unit (**km**) to a small unit (**m**), so you need to multiply (\times).
- Remember to include the unit you are converting to; in this case, metres (**m**).
- If converting in the opposite direction, from m to km, you divide by 1000.

- 2 Convert 150 grams to kilograms.

Answer: $150 \div 1000 = 0.15 \text{ kg}$

- There are 1000 grams in a kilogram, so the conversion factor is 1000.
- This conversion is from a small unit (**g**) to a big unit (**kg**), so you need to divide (\div).
- Remember to include the unit you are converting to; in this case, kilograms (**kg**).
- If converting in the opposite direction, from kg to g, you multiply by 1000.

- 3 Convert 4 hours to seconds.

1 hour = 60 minutes

1 minute = 60 seconds

1 (hour) \times 60 (minutes) \times

60 (seconds) = 3600 s

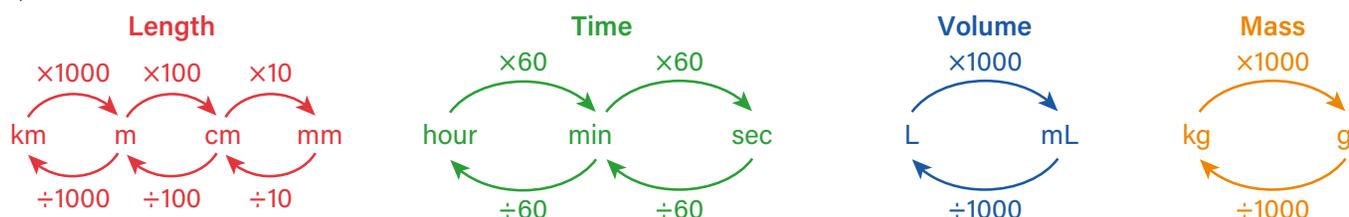
Answer: $4 \times 3600 = 14\,400 \text{ s}$

- You need to do two conversions here. Hours to minutes and then minutes to seconds. Start with calculating 1 hour in seconds.
- These conversions are both from big units to small units, so you need to *multiply* (\times). The conversion factors are both 60.
- Remember that there are 4 hours, so we need to multiply by 4 for the total number of seconds. Remember to include the unit you are converting to; in this case, seconds (**s**).

Figure S4.2:

Conversion charts for length, time, volume and mass

However, if you want to keep it simple, you can use conversion charts as shown in Figure S4.2, which provides the conversion factor and shows whether to multiply or divide, depending on which direction you are converting to. Worked example 2 has some examples.



Worked example 2: Converting between units using conversion charts

- 1 Convert 2.5 kilometres to metres.

Hint: you are converting to a *smaller unit*; therefore, you need to *multiply*.

The conversion from the chart is to multiply by 1000:

$$2.5 \times 1000 = 2500 \text{ m}$$

- 2 Convert 150 grams to kilograms.

Hint: you are converting to a *larger unit*; therefore, you need to *divide*.

The conversion from the chart is to divide by 1000:

$$150 \div 1000 = 0.15 \text{ kg}$$

- 3 Convert: 4 hours to seconds.

The conversion for 1 hour to seconds is to multiply by 60 to get minutes, then multiply by 60 again to get seconds. We also need to multiply by 4 to get 4 hours.

$$4 \times 60 \times 60 = 14\,400 \text{ s}$$

Figure S4.3:

The colours of Labrador puppies in a litter can be expressed as ratios.

Understanding ratios

Ratios are a way of comparing like quantities without units. For example, if a pancake recipe asks for one part milk and two parts flour, that is a ratio of 1 to 2. We can write this as 1:2. Ratios do not require units – no matter how much milk you use, you must always use twice as much flour ($\times 2$).

To identify a ratio, first count the total of each category and write the two totals (e.g. '10 to 20'), then replace the word 'to' with a colon, so '10:20'. Next, simplify the ratio by dividing both sides by a common factor. So, divide by 10 to get a ratio of 1:2.

For example, a black Labrador has eight puppies. Six are black and two are chocolate brown. Including the mother, there are nine dogs in total. Table S4.2 helps us to identify the different ratios for this example.



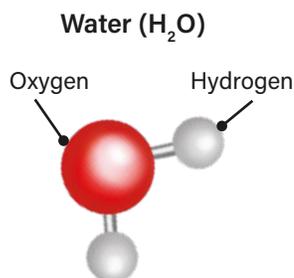
Table S4.2: Identifying ratios

Ratio	Initial count	Simplify	Answer
Black to chocolate puppies	Black = 6 Chocolate = 2 The ratio is 6:2.	Divide both numbers by the common factor of 2. $6 \div 2 = 3$ and $2 \div 2 = 1$ The simplified ratio is 3:1.	The ratio of black to chocolate puppies is 3:1.
Chocolate to black puppies	Switch the numbers around, as the question now asks about chocolate puppies first. The ratio is 2:6.	Divide by 2. $2:6 = 1:3$	The ratio of chocolate to black puppies is 1:3.
Black to total puppies	There are 6 black puppies and 8 puppies in total. The ratio of black puppies to total puppies is 6:8.	Divide by 2. $6:8 = 3:4$	The ratio of black to total puppies is 3:4.
Total to chocolate puppies	There are 8 puppies in total, and 2 chocolate puppies. The ratio is 8:2.	Divide by 2. $8:2 = 4:1$	The ratio of total to chocolate puppies is 4:1.
Chocolate puppies to black dogs	Black dogs = 7 (including the mother). The ratio is 2:7.	This cannot be simplified any further.	The ratio of chocolate puppies to black dogs is 2:7.

Ratios in science

We see ratios all the time in science. A chemical compound, for example, can be represented using a **chemical formula** based on the ratio of elements. We can use the chemical formula and the ratio to solve mathematical problems. The **subscript** to the right of each element is part of the ratio of atoms in the substance.

Water is a substance with the chemical formula H_2O . 'H' is the symbol for the element hydrogen and 'O' is the symbol for the element oxygen. A molecule of water contains 2 hydrogen atoms and 1 oxygen atom. This can be written as the ratio 2:1.



◀ **Figure S4.4:**
This model of water clearly shows the 2:1 ratio of hydrogen to oxygen.

Worked example 3: Ratios in a chemical mixture

How many carbon atoms will there be if there are 40 hydrogen atoms?

1 C_3H_8 .

The ratio of carbon atoms to hydrogen atoms is 3:8.

- This means there are 3 carbon atoms and 8 hydrogen atoms in a molecule of propane.
- The coloured subscript numbers indicate how many atoms there are in the molecule.

2 Turn 3:8 into a fraction.

$$\frac{\text{carbon atoms}}{\text{hydrogen atoms}} = \frac{3}{8}$$

- Ratios can be written as fractions.

3 Work out how many carbon atoms we will have if we have 40 hydrogen atoms given the ratio is 3:8.

$$40 \div 8 = 5$$

- Divide 40 by 8 to find the **scale factor**.
- The scale factor is 5.

4 Multiply the *numerator* x 5 to get the number of carbon atoms.

$$3 \times 5 = 15$$

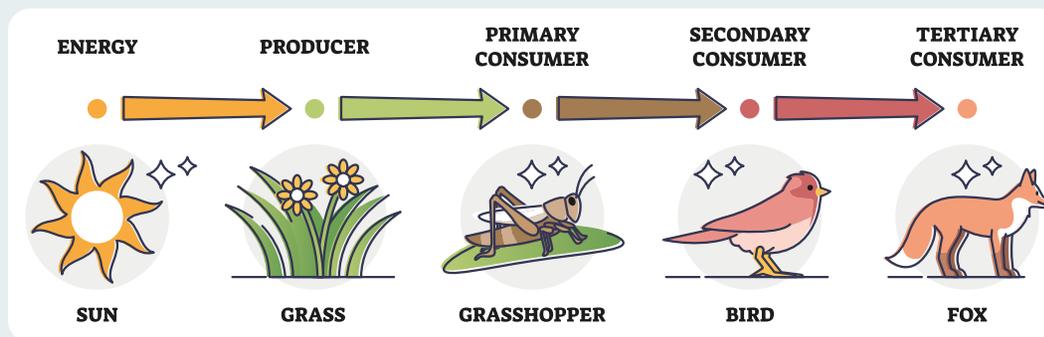
- The numerator is 3.
- Multiply 3 by 5 (because 5 is the scale factor).

5 Answer: There will be 15 carbon atoms if there are 40 hydrogen atoms.

Ratios can also be used to carry out calculations based on relative comparisons like percentages, as shown in Worked example 4.

Worked example 4: Calculating energy transfer in a food chain

A diagram of a food chain is shown in Figure S4.5. Each level up in a food chain only receives about 10 per cent of the energy from the level below. For example, grass would have to store 10 joules (J) of energy for a grasshopper to receive 1 J of energy when it eats the grass. The ratio is therefore 1:10, and the scale factor from a lower level to the next level is 10.



◀ **Figure S4.5:**
Energy moves up a food chain.

Question: How much energy would a grasshopper need to store to provide a bird with 630 joules of energy?

$$630 \times 10 = 6300 \text{ J}$$

Answer: The grasshopper needs to store 6300 J of energy to provide the bird with 630 J of energy.

- A bird needs 630 J of energy from a grasshopper, but only 10 per cent of the grasshopper's energy store passes up the food chain to the bird.
- This 10 per cent is the *scale factor*.
- Therefore, you multiply 630 by 10.

Calculating averages

Mean, median, mode and *range* are terms you will often hear when working with data. Mean, median and mode are different ways to measure the centre of the data. Each is used in different situations for different purposes, depending on what you are trying to understand. Range is used to understand the spread of numbers in a dataset. We will go through each of them in turn.

Mean

The **mean** (often called the average) can be used when many measurements are taken of the same thing and you want a value near the centre of all the measurements. This value is often required in scientific investigations when you have conducted multiple trials. The mean is often used in visual representations of the data.

The mean equals the sum of all values divided by the total number of values.

Here is a set of values: 5, 8, 9, 11, 12.

To arrive at the mean or average of the set of values, add them together:
 $5 + 8 + 9 + 11 + 12 = 45$. Then divide 45 by the number of values (in this case, 5 values) to calculate the mean.

The mean is $45 \div 5 = 9$.

See Worked example 5 on the next page.

Worked example 5: Calculating the mean

Newcastle recorded the following temperatures over four consecutive days in January: 29 °C, 39 °C, 35 °C and 33 °C. Calculate the mean of this data.

- 1 Mean = sum of all the values
(add the values up) divided by
the total number of data values

- Identify the formula for calculating the mean.

2 $\frac{29 + 39 + 35 + 33}{4}$

- Substitute the known values into the formula.
- There are four temperature readings, so the total number of data values is 4.

3 $\frac{136}{4} = 34$

- Solve for the mean.

- 4 Answer: the mean is 34 °C.

- Remember to include any units of measurement (in this case, °C) in your answer.

Median

The **median** is the middle value in a group of values. In the set of values 5, 8, 9, 11, 12, the middle value is 9. Therefore, the median is 9.

Mode

The **mode** is the most frequent value in a dataset. If you are asked to identify the mode, look for the value that occurs the most often. For example, in the group of values 2, 4, 5, 2, 6, 2, the mode is 2 because it occurs 3 times.

Range

The **range** is the difference between the smallest and largest values in a dataset. In the group of values 5, 8, 9, 11, 12, the smallest value is 5 and the largest value is 12. The range is the difference between them: $12 - 5 = 7$. Therefore, 7 is the range of this dataset.

Percentages

Percentages tell you what part of the whole you have. One hundred per cent (100%) is the whole thing, so percentages should always add up to 100. Percentages are another way to represent a fraction or decimal, as shown in Table S4.3. A percentage is converted to a decimal by dividing by 100.

Table S4.3: Percentage can be represented in fraction or decimal form.

Percentages	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Decimals	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Fractions	$\frac{0}{10}$	$\frac{1}{10}$	$\frac{2}{10}$	$\frac{3}{10}$	$\frac{4}{10}$	$\frac{5}{10}$	$\frac{6}{10}$	$\frac{7}{10}$	$\frac{8}{10}$	$\frac{9}{10}$	$\frac{10}{10}$

Use the following basic formula to calculate percentage:

$$\text{Percentage} = \frac{\text{the part of something you want the percentage of}}{\text{the whole thing}} \times 100$$
$$\% = \frac{\text{part}}{\text{whole}} \times 100$$

If someone wants to eat three pieces of this pizza, what percentage of the pizza will they eat?

- 1 3 out of 10 pieces were eaten.
- 2 $\text{Percentage} = \frac{\text{part}}{\text{whole}} \times 100$
- 3 $\text{Percentage} = \frac{3 \text{ [pieces]}}{10 \text{ [total pieces]}} \times 100$
- 4 $\text{Percentage} = 0.3 \times 100 = 30\%$

Table S4.3 also shows you that

$$30\% = \frac{3}{10} = 0.3.$$

The person will eat 30 per cent of the pizza if they eat 3 slices out of 10.



Figure S4.6: If a pizza is cut into 10 equal pieces, each piece represents 10 per cent.

Worked example 6: Calculating percentages

There is 41 500 000 cubic kilometres of fresh water on Earth, but only 6 225 000 cubic kilometres is available to use. What percentage of fresh water on Earth is available?

- 1 $\text{Percentage} = \frac{\text{part}}{\text{whole}} \times 100$ — Identify the formula for calculating percentage.
- 2 The part = available fresh water = 6 225 000 km³
The whole = total fresh water = 41 500 000 km³ — Identify and label the values given in the question.
- 3 $\text{Percentage} = \frac{6\,225\,000}{41\,500\,000} \times 100$ — Substitute the given values into the formula. You might need to use your calculator.
 $\text{Percentage} = 0.15 \times 100 = 15\%$
- 4 Answer: Available freshwater is 15%. — The term 'per cent' or the percentage symbol (%) must always accompany a percentage value.

This formula can be adapted to suit a variety of situations, as shown in Worked example 7.

Worked example 7: Energy efficiency and percentages

Your hair dryer uses 28 000 joules of energy but only puts out 15 960 joules of blowing energy. What is the percentage efficiency of your hair dryer?

- 1 Percentage = $\frac{\text{part}}{\text{whole}} \times 100$ ————— Identify the formula for calculating percentage.
- 2 Efficiency = $\frac{\text{part}}{\text{whole}} \times 100$
Efficiency = $\frac{\text{blowing energy}}{\text{total}} \times 100$ ————— Adapt the formula to suit the problem. We are trying to work out the *efficiency* of the hair dryer.
- 3 The part = blowing energy = 15 960 J
The whole = total energy = 28 000 J ————— Identify and label the values given in the question.
- 4 Efficiency = $\frac{15\,960}{28\,000} \times 100$ ————— Substitute the given values into the formula. You might need to use your calculator to work this out.
Efficiency = $0.57 \times 100 = 57\%$
- 5 Answer: The efficiency of the hairdryer is 57%. ————— The term 'per cent' or the percentage symbol (%) must always accompany a percentage value.

There is a lot more to learn about percentages and how they are used in science, including how to calculate percentage error. You will learn more about this in later years.

Scientific notation

Scientific notation, sometimes called standard form, helps us to write very large or very small numbers in a simpler way. Every number can be written in scientific notation as the product (product = multiply, or times) of two numbers that are:

- a decimal greater than or equal to 1 and less than 10
- a **power** of 10 written as an **exponent**. (An example of an exponent is 10^3 , which is the same as $10 \times 10 \times 10$. The '3' (a **superscript**) means that the 10 is multiplied by itself 3 times.)

2.56×10^3 is an example of scientific notation. It is a different way of writing the number 2560. It is the same as writing $2.56 \times 10 \times 10 \times 10$.

Scientific notation becomes really useful when you work with very big and very small numbers. For example, 2.56×10^7 is the same as writing $2.56 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10$, which equals 25 600 000. It is faster and easier to write 2.56×10^7 . The bigger or smaller the number, the more useful it becomes.

In Worked examples 8 and 9, we will explore writing large and small numbers in scientific notation.

Worked example 8: Scientific notation for large numbers

1 Write 65 000 000 in scientific notation.

- 65 million is a very large number.

2 Turn 65 000 000 into a decimal > 1 and < 10 .

6.5 000 000

- To write a number in scientific notation, you need two things: a decimal greater than or equal to 1 and less than 10, and a **power** of 10. To create your decimal, you need to move the decimal point at the end of 65 000 000 left 7 times. (Think of 65 000 000 as 65 000 000.0.)

It becomes 6.5 000 000.

3 Answer: 65 000 000 in scientific notation is 6.5×10^7 .

- The number of times you move the decimal point to the left becomes the power you need to write your number as in scientific notation. You moved the decimal point 7 times, so the power is 10^7 . It is a positive power.
- Remember: when you are expressing a very large number in scientific notation, move the decimal point *left* to create your decimal. Your power will be *positive*.

Worked example 9: Scientific notation for small numbers

1 Write 0.000 009 8 in scientific notation.

- 0.000 009 8 is a very small number less than 1.

2 Turn 0.000 009 8 into a decimal ≥ 1 and < 10 .
It becomes:

0.0000098

- To write this in scientific notation, you must have the same two things: a decimal greater than or equal to 1 and less than 10, and a power of 10.

It becomes 9.8.

3 Answer: 0.000 009 8 in scientific notation is 9.8×10^{-6} .

- The number of times you move the decimal point to the right becomes the power you need to write your number as in scientific notation. But because your number is less than 1, your power is **negative**. You moved the decimal point right 6 times, so the power is 10^{-6} .
- Remember: when you are expressing a very small number in scientific notation, move the decimal point *right* to create your decimal. Your power will be *negative*.

If you want to convert your numbers back from scientific notation into decimal notation, you reverse the method. If the power is positive, move the decimal point to the right to make the number larger; and if the power is negative, move the decimal point to the left to make the number smaller:

$$3.2 \times 10^4 = \text{move the decimal point 4 places to the right} = 32\,000$$

$$3.2 \times 10^{-4} = \text{move the decimal point 4 places to the left} = 0.00032$$

Table S4.4 compares several examples of decimal notation to scientific notation.

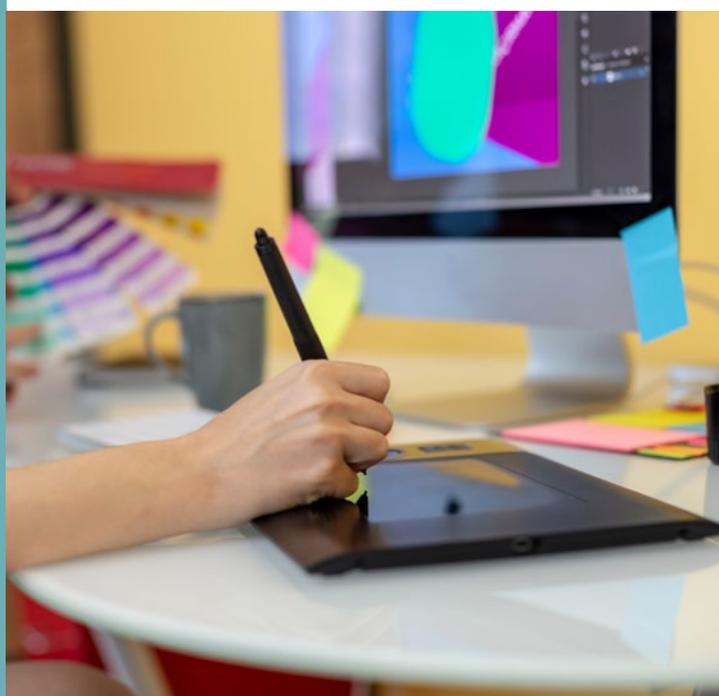
Table S4.4: Comparing decimal and scientific notation

Decimal notation	Scientific notation
6	6×10^0 (10 to the power of zero is 1)
500	5×10^2
4323.7	4.3237×10^3
0.0043237	4.3237×10^{-3}
-23 000	-2.3×10^4
5830000000	5.83×10^9
0.9	9×10^{-1}
0.0000000351	3.51×10^{-8}

Graphing

Graphing data is an excellent way to visually represent the quantitative information you have gained from a first-hand investigation. The type of data will determine the type of graph to make. In first-hand investigation reports, this is usually a scatter plot or a column graph.

Figure S4.7: Different graph formats help us to make sense of information in different ways.



Scatter plots

Scatter plots are used when two pieces of data are directly related and show trends, such as a change over time. When looking at trends, a line graph is useful as it can show increases and decreases very clearly. For example, in a particular city, the percentage of new cars sold that had airbags was recorded each year. The results were 18% in 2018, 24% in 2019, 32% in 2020, 45% in 2021 and 60% in 2022. This data could be displayed in a line graph.

Remember that the independent variable (changed factor) should go on the horizontal axis, the x-axis. In this case, that would be the year the car was sold. The dependent variable (measured factor) should go on the vertical axis, the y-axis. This would be the percentage of cars with airbags. Each axis should have a label and an even scale.

Plotting points

Once you have drawn an even scale, you can plot the points on the graph:

- 1 Locate the relevant data on the x-axis (e.g. year 2018).
- 2 Locate the relevant data on the y-axis (e.g. percentage 18%).
- 3 Trace on the graph to where the two points meet.
- 4 Where the points intersect, plot the point by drawing an 'x' on the spot.
- 5 Continue plotting points for each piece of data.

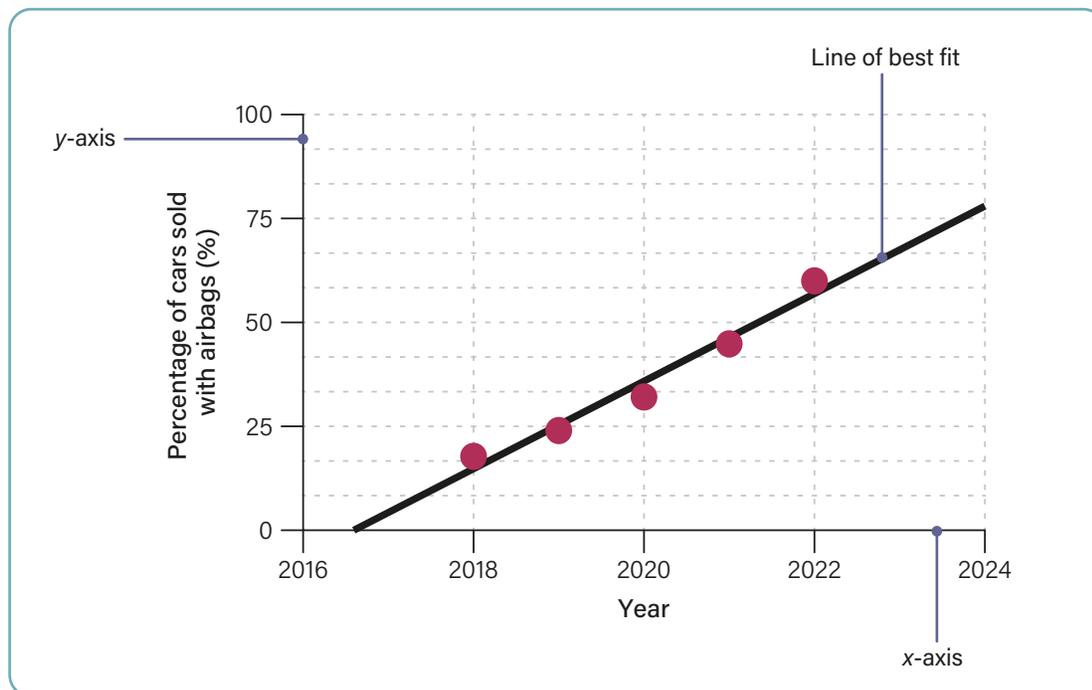
Line of best fit

Once all of the data points are on your graph, you can add a trend line, known as the 'line of best fit'. This line will go through the middle of most of the points, but will not necessarily connect the dots between each. A line of best fit can be straight (ruled) or curved, depending on the data. Use the following instructions to draw a line of best fit:

- 1 Look at all the points on the graph. Do they make a straight or curved line?
- 2 For a straight line, place a ruler on the graph, through the points. Move it until most of the points are close to or touching the line. Carefully rule the line on the graph, continuing past the final point to the end of the x-axis.
- 3 For a curved line, carefully sketch a single line curve through the data points, and continue it to the very top of the graph, or the edge of the x-axis.

Your finished graph should look similar to Figure S4.8.

Figure S4.8 shows a scatter plot for the data given in the example. From this graph, we can see a *trend*. A trend describes what the data is showing. In this case, cars sold with airbags are increasing as the years increase. This is a positive trend.



◀ **Figure S4.8:** Percentage of cars sold with airbags (%) per year, 2016–2024

Column graphs

Column graphs are used to compare separate categories of the same type of data. This means that there is a distinction between the independent variables – each is its own separate category. However, they are still measured against the same criterion.

For example, in City X the average daily maximum temperature for the month was recorded for every month of a year (2024). The results were 33 °C in January, 30 °C in February, 25 °C in March, 19 °C in April, 17 °C in May, 12 °C in June, 8 °C in July, 10 °C in August, 13 °C in September, 20 °C in October, 27 °C in November and 31 °C in December. This data could be displayed in a column graph.

Remember that the independent variable (changed factor) should go on the horizontal x-axis. In this case, it is the month of the year. The dependent variable (measured factor) should go on the vertical y-axis. This is the temperature in degrees Celsius (°C). Each axis should have a label and an even scale.

Adding columns

Once you have drawn an even scale, add the columns to the graph:

- 1 Locate the relevant data on the x-axis, such as the month of January.
- 2 Locate the relevant data on the y-axis, such as the temperature of 33 °C.
- 3 Trace on the graph to where the two points meet.
- 4 Where the points intersect, put a small pencil mark.
- 5 Using a ruler, extend the point out on each side of the mark, and then down to the x-axis to make a column.
- 6 Continue for each piece of data on the x- and y-axes.

A completed column graph from the data above should look similar to Figure S4.9.

Note: If you prefer, the data represented as a column graph here could also be represented as a line graph.

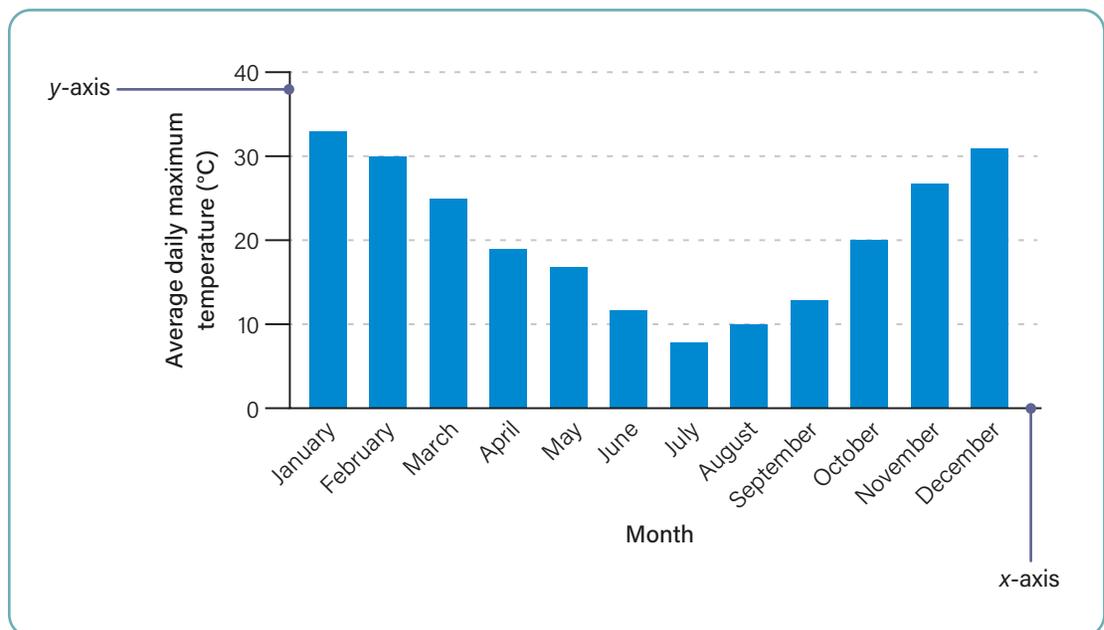


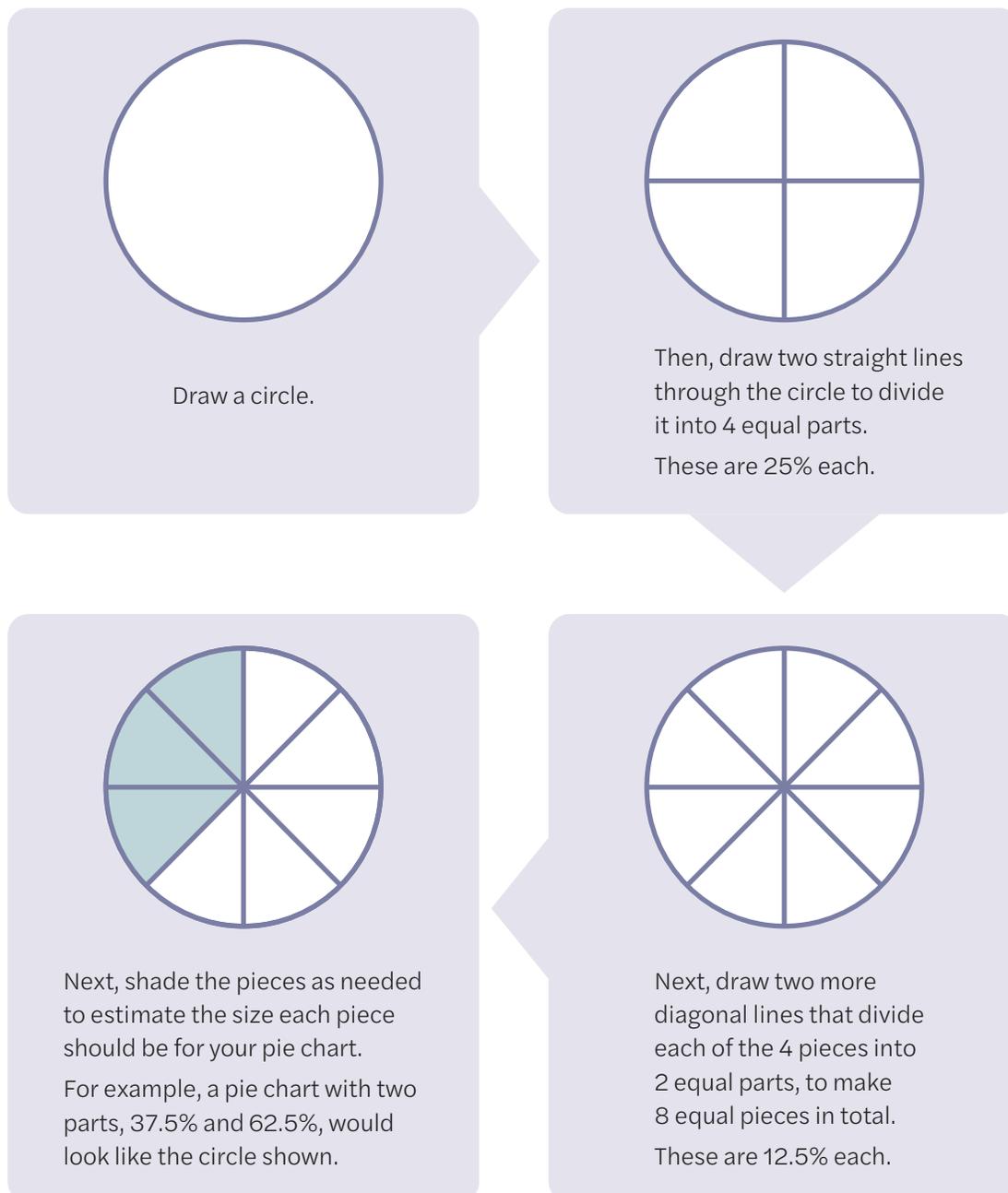
Figure S4.9: ▶ Average daily maximum temperature across months of the year in City X, 2024

Making pie charts

A pie chart is a visual representation of parts of a whole. The 'pie' is a circle where each 'piece' represents a fraction or percentage. Therefore, the whole circle represents the whole thing: 100 per cent.

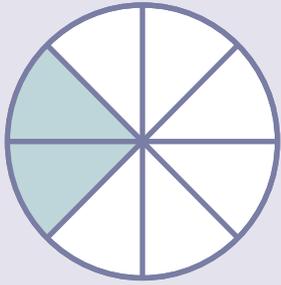
To make a pie chart, the size of each 'piece' should reflect the percentage it represents. So, if one of the parts is 25 per cent, that piece should take up a quarter of the pie, which is 25 per cent.

When there are lots of parts, it can be difficult to estimate the size of each piece by hand. Ideally, you should use a computer program like Microsoft Excel, or an app for making pie charts, to ensure your pieces are the right size for each part they represent, but if you are creating your pie chart by hand, you can estimate. A helpful way to approach this is to divide your circle into eight equal pieces. Each piece is 12.5 per cent of the circle, which will help you to make your estimates.

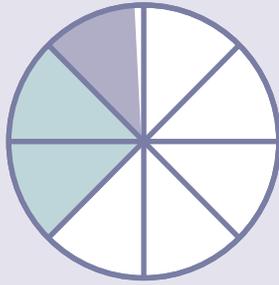


◀ **Figure S4.10:**
How to create a simple pie chart using estimates

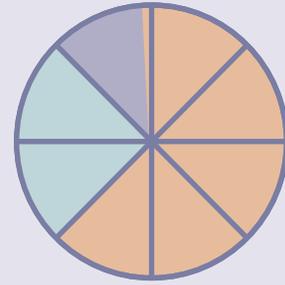
Let us say the percentages you want to represent in a pie chart are 25, 12 and 63.



- Start with the pie divided into 8 pieces.
- If any of the parts are exactly 12.5% or multiples of 12.5%, shade those first.
- 25% is 12.5×2 , so this is a good part to shade first in your pie chart, using 2 pieces to represent 25%.



- The next value to represent in your pie chart is 12%.
- Since each piece is 12.5%, you will estimate the part to be slightly smaller than one piece of the pie.
- Shade this in a different colour to the 25% part.



- The remaining part should be 63% of the circle. This is about 5 pieces ($5 \times 12.5\% = 62.5$). So, shade 5 more pieces, plus the tiny bit of the piece left over from the 12% part. Use a third colour for the third part of the pie.
- You have created this by hand, so it may not be exact, but using the 12.5% pieces to estimate will help your pie chart be as accurate as possible when digital tools are not available.

▲ **Figure S4.11:** Representing three amounts in a pie chart using estimates

This is one way to estimate the size of the pieces of a pie chart when drawing by hand. Other ways are to use a tape measure, a protractor or a circle with 10 equal pieces that are 10 per cent each. However, when you need to formally present your information, it is best to create the pie chart digitally, to make it as exact as possible.

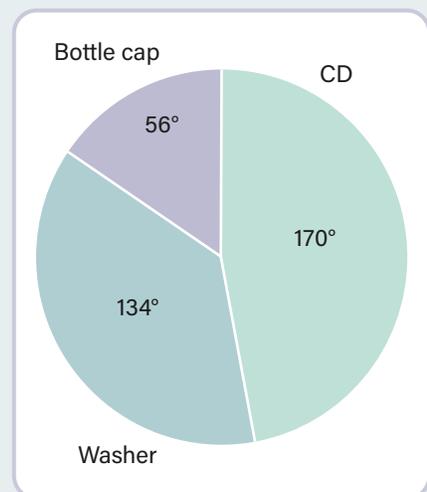
Worked example 10: Drawing pie charts

To create each sector, first add up the total distance. In our investigation results, Table S2.5 on page 241, the total distance all three wheels travelled is 70 centimetres. Using a calculator, divide each distance by the total distance, then multiply it by 360 degrees to find the angle for each sector, as shown in Table S4.5.

Table S4.5: Average distance and sector angles

Wheel type	Average distance (cm)	Sector angle
Bottle cap	11	$11 \div 70 \times 360 = 56$ degrees
CD	33	$33 \div 70 \times 360 = 170$ degrees
Washer	26	$26 \div 70 \times 360 = 134$ degrees

Draw a circle, locate the centre and draw a radius from the top to the centre. Measure the largest angle from that radius line to make the first sector (in this case, 170 degrees). Starting from the new line, measure the next angle and repeat until finished. If your data is given as percentages, then find that percentage of 360 degrees to determine the angles.



▲ **Figure S4.12:** The finished chart clearly shows each part of the whole distance.

Using formulas to determine an unknown value

Mathematical formulas are used to show the mathematical relationship between variables. Often, you will be given all the values of variables in a particular **equation** except for one (the unknown). You can use the formula to solve the equation to find the unknown. However, before you apply a formula, you need to determine which formula will be best to use.

Follow these steps to identify and use scientific formulas to determine an unknown value:

- 1 Read the question carefully. Identify and label the values that are given in the question, and the variable you are trying to determine.
- 2 Consider the variables you have listed. Identify the formula that includes those variables.
- 3 Rearrange the formula, as needed, based on your unknown variable, and substitute in known values.
- 4 Solve for the unknown, keeping the same units as indicated by the given values, or convert units if required by the question.

To practise these steps, we will look more closely at a specific formula.

Density is a measure of how heavy something is compared to how much space it takes up. This relationship can be shown mathematically:

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

When we replace the words with their symbols (in *italics*), it is now a formula equation:

$$d = \frac{m}{V}$$

Worked example 11 will help you to understand how to use this formula to determine an unknown value.

Worked example 11: Choosing a formula to determine an unknown value

You pour a cup of tea and measure a volume of 30 millilitres of honey into it. Your tea now weighs (has a mass of) 42 grams more than before the honey was added. What is the density of the honey?

- 1 mass, $m = 42$ g
volume, $V = 30$ mL
density, $d = ?$

- Collect the information you have been given:
You know the volume of honey and the mass of the tea.
You do not know the density of the honey. That is what you are trying to work out.

2 $d = \frac{m}{V}$

- Choose the formula that allows you to use the information you have collected. The formula is for density.

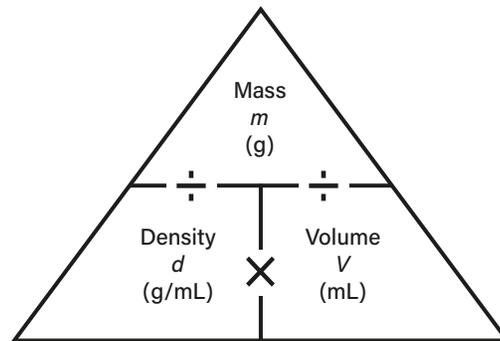
3 $d = \frac{42}{30}$

- Calculate the density of the honey by substituting the known values into the formula. (You can use your calculator.)

4 Answer: $d = 1.4 \text{ g/mL}$

- $42 \div 30 = 1.4$
- Remember to use the same units as the given values in your answer.

The density formula can be rearranged to determine mass or volume, if you know the other two variables. For example, if you are solving for mass, the formula is rearranged to $m = d \times V$. If you know the mass and density, the formula to solve for volume is $V = m/d$.



S5

Using scientific equipment

Good science involves curiosity, a desire to understand the world, and a passion for improvement and innovation. Good science also means conducting investigations safely and accurately, which includes knowing your equipment and how to use it. In this section, we will familiarise ourselves with common equipment.

Safety

Conducting investigations in a safe manner is key to good science. Follow laboratory safety rules to ensure you minimise risk. Use the acronym PIECE to remember these safety rules.

Key terms

concave: hollowed or rounded inwards

meniscus: the curve seen at the top of a liquid in its container

parallax error: the apparent shift in something's position when it is viewed from different angles

surface tension: where the molecules at the surface of a liquid are more attracted to each other than to the air above the liquid

Figure S5.1: Working with chemicals requires following safety information and wearing personal protective equipment (PPE).



Protective equipment: Wear safety glasses, gloves and a laboratory coat to protect you from any chemical splashes or spills.

Instructions: Listen to and read all instructions carefully before you start your investigation.

Equipment: Inspect all equipment to make sure you have the correct items for your specific investigation. Ensure equipment is intact and working properly.

Consumption: Food and drink can become contaminated. Never bring or consume food or drink in the laboratory.

Energy: Manage your energy levels so that you are walking sensibly and holding equipment securely while moving around the lab.

Pictograms

Pictograms are a part of science safety. They are used to label chemicals with their known hazards. Figure S5.2 shows some pictograms you are likely to see in the laboratory.

Pictograms are used across many industries, so you may recognise them from cleaning products used in your home. Pay close attention to the pictograms on the chemicals you use in the laboratory and follow any warnings. Some chemicals may not be hazardous, so you will not see any pictograms. Others may have several hazards and contain several pictograms for a single substance.

There are many more pictograms than the ones shown here, so be sure to ask your teacher if you come across an unknown pictogram.

Figure S5.2: ▶
Common warning pictograms



Flammables



Gases under pressure



Acutely toxic



Burns skin, damages eyes, corrosive to metals



Explosives



Oxidisers



Toxic to aquatic environment



Health hazard

(Chronic health hazards, denoted by the health hazard pictogram, include carcinogens, reproductive toxins, mutagens, specific target organ toxicants, and aspiration toxicants.)



Acutely toxic (harmful)

(Other health hazards, denoted by the exclamation mark pictogram, include skin, eye and respiratory irritation, allergic skin reactions, drowsiness and dizziness.)



▲ **Figure S5.3:** Pictograms show the chemicals in your laboratory that are hazardous.

Laboratory equipment

Get to know common laboratory equipment

By learning the names and uses of laboratory equipment, you can select and use the correct equipment for any investigation. Some of the most common equipment is shown here.

Figure S5.4:
Laboratory equipment



Measurements in science

As discussed earlier, scientists use specialised equipment to measure temperature and volume. In the school laboratory, we measure temperature in degrees Celsius ($^{\circ}\text{C}$) using thermometers. We also measure volume in litres (L) and millilitres (mL) using measuring cups and beakers. By measuring things carefully, scientists can report their findings reliably.

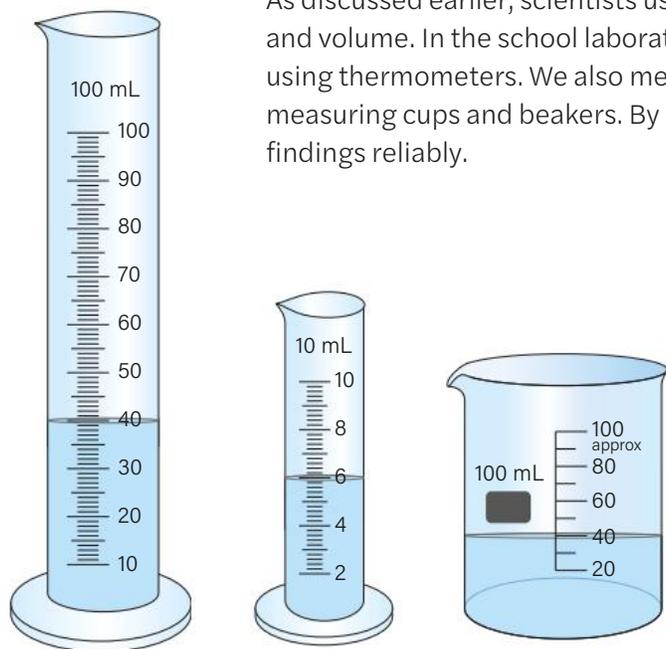


Figure S5.5:
Beakers and
measuring cylinders

Volume measurements

Reading volume measurements is not as easy as it might seem. It requires an understanding of how liquids can curve and the ability to take this into account. You need to use specific equipment, which will help you to measure accurately.

Equipment for measuring volume

Beakers and measuring cylinders are the most common pieces of equipment you will use to measure volume. As they are filled with liquid, the measurement reading increases.

When precision matters, always use the smallest measuring cylinder available that can measure the required amount. For example, if you need to measure 8.0 mL of something, it is best to use a 10 mL measuring cylinder to get the most accurate result.

Observing the meniscus

Because of **surface tension**, liquids do not form a flat surface in a relatively small container. Instead, a curve forms, which is called the **meniscus**. You should take volume readings at eye level, at the very bottom of a **concave** meniscus, as shown in Figure S5.6. It is obvious that the bottom of the meniscus is between the 36 mL and 37 mL increment lines, which is recorded with certainty. The place value after the increment marks – in this case, the tenth place (.0) – should be estimated. Therefore, the measurement for this volume is 36.5 mL, where the .5 is uncertain.

If you do not take the reading at eye level, **parallax error** will occur. If this happens repeatedly, you will have a systematic error in your measurement, because the error will be the same for all readings. Figure S5.7 shows how reading the meniscus above eye level results in a low reading as compared to the true value, and reading the meniscus from below gives a higher value.

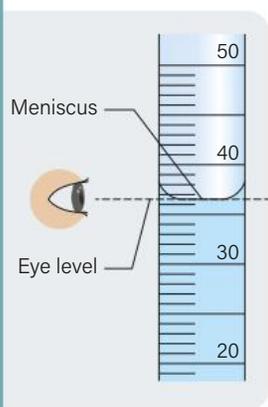


Figure S5.6:
Take volume
readings at
eye level.

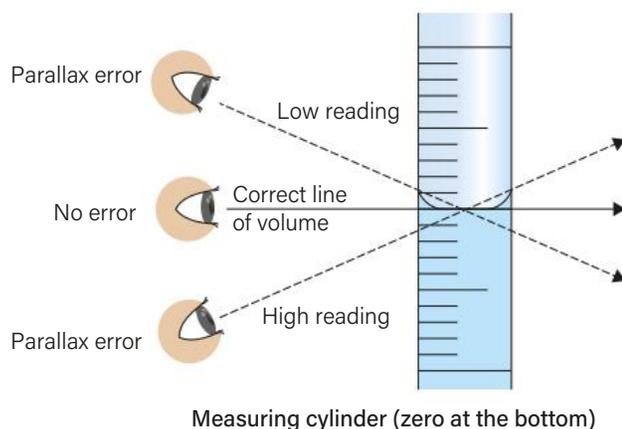


Figure S5.7:
To avoid parallax
error bring yourself
down to the
appropriate level.
This takes practice.

Measuring cylinder (zero at the bottom)

Light microscope

The most common type of microscope in the school science laboratory is a light microscope. It allows you to study samples by shining a bright light through an extremely thin slice of material. The image is magnified by the microscope's lenses, which you look through.

The eyepiece of a light microscope already magnifies samples by 10 times. The objective lens, which is lower down and usually rotates, then magnifies samples by a further amount. To identify the total magnification, multiply the eyepiece magnification (10) by the objective lens magnification.

Figure S5.8: A light microscope can usually magnify samples by up to 400 times.

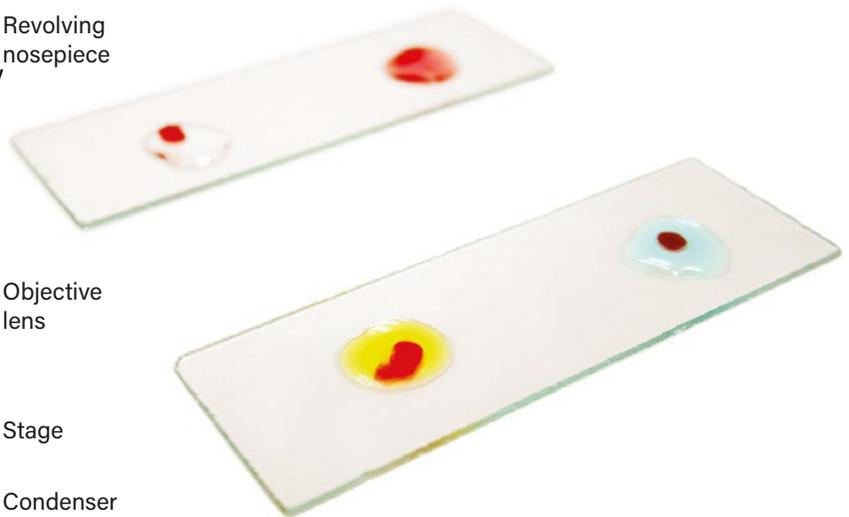
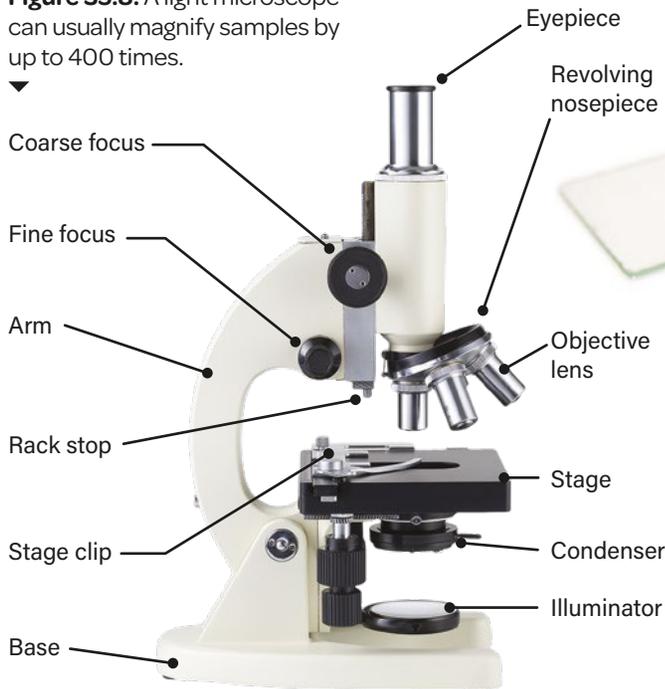


Figure S5.9: Microscope slides are usually made of glass and are very fragile – treat them carefully.

Setting up and using a light microscope

- 1 Place your microscope on the bench or table, making sure that it is not too close to the edge and that the arm is facing you.
- 2 Plug your microscope in and turn it on. The illuminator (light) will come on.
- 3 Lower the stage as far as it can go, using the coarse focus knob.
- 4 Consider each of the rotating objective lenses. Often they are different colours and have the magnification written on them.
- 5 Start with the lowest magnification – this is usually 4× (four times). Your microscope eyepiece already has a 10× magnification on its own, so when coupled with the 4× eyepiece, what you are looking at will be 40 times the actual size.
- 6 Carefully insert the microscope slide onto the top of the stage and hold it firmly under the stage clip. Position it so the object you need to see is in the middle of the stage.
- 7 Look through the eyepiece and slowly bring the stage upwards towards you, using the coarse focus knob. This can take some time and everything will look bright and fuzzy until you get a glimpse of the slide as it comes into focus.
- 8 When the slide is roughly in focus, use the fine focus to turn it into a clear image.
- 9 Increase the magnification by changing the objective lens to 10×, 20× or 40×.
- 10 40× is usually the highest available magnification and can be tricky to find and focus on. It can also bring the lens extremely close to the slide, enough to crack and break it – monitor this carefully.

Investigations

Investigation number	Investigation title	Inquiry skill	Inquiry skill focus	Teacher demonstration
Chapter 1 Cells		Questioning and predicting, Planning and conducting		
1.1	Examining cells under a microscope	Questioning and predicting	Constructing scientific questions	
1.2	Examining cell structures	Planning and conducting	Generating and recording data	
1.3	Observing unicellular organisms	Planning and conducting	Describing ways to minimise risk	
1.4A	Investigating respiration	Planning and conducting	Distinguishing between variables	
1.4B	Energy from food	Planning and conducting	Generating and recording data	
Chapter 2 Systems of living things		Questioning and predicting, Communicating		
2.3	Breathing rate and exercise	Communicating	Identifying scientific terminology	
2.4	Dissecting a heart	Questioning and predicting	Constructing scientific questions	
2.7	Water transport in plants	Questioning and predicting	Making predictions	
2.8	Dissecting a flower	Communicating	Preparing representations to communicate findings	
Chapter 3 Organising matter		Planning and conducting, Processing, modelling and analysing		
3.2	Comparing metals and non-metals	Planning and conducting	Identifying scientific equipment	
3.3	Investigating the different properties of a compound and one of its elements	Planning and conducting	Describing ways to minimise risk	
3.4	Separating a mixture	Processing, modelling and analysing	Identifying data	
3.5	Comparing the properties of elements, compounds and alloy mixtures	Planning and conducting	Generating and recording data	
3.6	Making a molecular modelling kit	Processing, modelling and analysing	Analysing scientific models	
3.7	Modifying metals	Planning and conducting	Distinguishing between variables	

Investigation number	Investigation title	Inquiry skill	Inquiry skill focus	Teacher demonstration
Chapter 4 Chemical change		Planning and conducting, Evaluating		
4.1	Observing physical and chemical changes	Planning and conducting	Identifying scientific equipment	✓
4.2	Burning steel wool	Evaluating	Identifying investigation errors and assumptions	✓
4.3	Law of conservation of mass	Planning and conducting	Generating and recording data	
4.5	Identifying gases produced in chemical reactions	Evaluating	Supporting findings with evidence	
4.6	Exothermic and endothermic reactions	Evaluating	Describing types of errors	
Chapter 5 Plate tectonics		Planning and conducting, Evaluating		
5.1	Modelling Earth's structure	Planning and conducting	Identifying scientific equipment	
5.2	Modelling seafloor spreading	Evaluating	Constructing evidence-based arguments	
5.3A	Modelling slab pull	Planning and conducting	Designing scientific investigations	
5.3B	Observing convection currents	Planning and conducting	Describing ways to minimise risk	
5.4	Slinky waves	Planning and conducting	Distinguishing between variables	
5.5A	Viscosity of lava	Evaluating	Constructing evidence-based arguments	
5.5B	Wax volcano	Evaluating	Supporting findings with evidence	

Investigation number	Investigation title	Inquiry skill	Inquiry skill focus	Teacher demonstration
Chapter 6 The rock cycle		Processing, modelling and analysing, Communicating		
6.1A	Observing minerals	Processing, modelling and analysing	Organising data	
6.1B	Extracting copper	Processing, modelling and analysing	Identifying data	
6.2	Modelling the rock cycle	Communicating	Identifying scientific terminology	
6.3A	Cooling rate and crystal size	Processing, modelling and analysing	Identifying and discussing trends in data	
6.3B	Observing igneous rocks	Processing, modelling and analysing	Organising data	
6.4A	Modelling contact metamorphism	Communicating	Preparing representations to communicate findings	
6.4B	Observing metamorphic rocks	Communicating	Using digital technologies to communicate findings	
6.5A	Modelling the formation of sandstone	Processing, modelling and analysing	Analysing scientific models	
6.5B	Observing sedimentary rocks	Processing, modelling and analysing	Organising data	
6.6	Making 'fossils'	Communicating	Presenting scientific findings	
Chapter 7 Energy		Processing, modelling and analysing, Communicating		
7.1	Rolling balls	Communicating	Presenting scientific findings	
7.2A	Conduction: heat energy transfer in a solid	Communicating	Identifying scientific terminology	
7.2B	Convection: heat energy transfer in a liquid	Communicating	Preparing representations to communicate findings	
7.3	Energy transformations	Processing, modelling and analysing	Identifying and discussing trends in data	
7.5	Comparing energy in appliances	Processing, modelling and analysing	Processing data	
7.6	Thermal energy and colour	Communicating	Preparing representations to communicate findings	
7.7	Insulation and heat transfer	Processing, modelling and analysing	Identifying and discussing trends in data	
7.8	Household energy audit	Processing, modelling and analysing	Identifying and discussing trends in data	
Chapter 8 Electricity		Questioning and predicting, Evaluating		
8.1	Magnetic shielding	Questioning and predicting	Making predictions	
8.2	Charging balloons	Evaluating	Constructing evidence-based arguments	
8.5A	Modelling a simple circuit	Evaluating	Supporting findings with evidence	
8.5B	Conductors and insulators	Evaluating	Describing types of errors	
8.6	Exploring Ohm's law	Questioning and predicting	Developing a hypothesis	
8.7	Series and parallel circuits	Evaluating	Supporting findings with evidence	
8.8	Short circuits	Questioning and predicting	Making predictions	✓

Examining cells under a microscope

Inquiry skill: Questioning and predicting

Inquiry skill focus: Constructing scientific questions

Scientific investigations are based on scientific questions constructed by scientists wanting to learn more about the world. These questions aim to identify a relationship or connection between an independent variable (the factor being changed) and a dependent variable (the factor being measured).

Hint 1: What should a good question look like?

Hint 2: More information about constructing scientific questions is available in the Science how-to section on page 234.

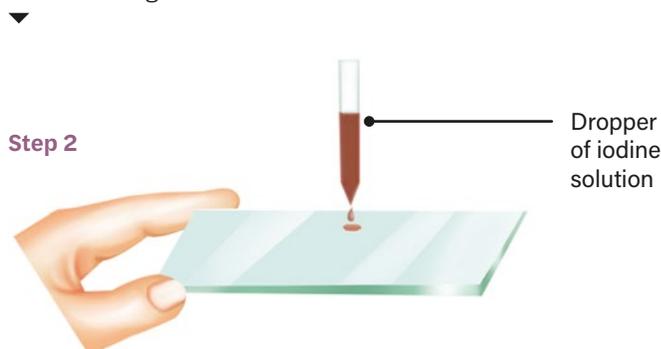
Aim

To investigate the cells in onion tissue under a microscope

Materials

- microscope slides and coverslips
- dropper bottle of weak iodine solution (1.3 per cent concentration)
- knife and chopping board
- slice of onion
- tweezers (or forceps)
- blunt dissecting needle (or a probe or a sharp pencil)
- paper towel
- light microscope

Figure INV1.1a: Steps 2, 6 and 7 of this investigation

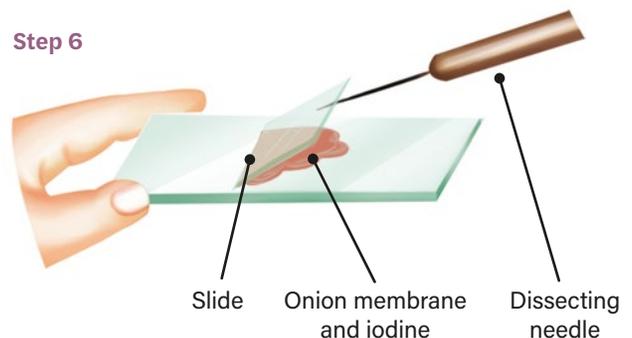


BE CAREFUL USING A KNIFE. MICROSCOPE SLIDES ARE MADE OF GLASS AND CAN BREAK EASILY. IF YOU CUT YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND SEEK FIRST AID.

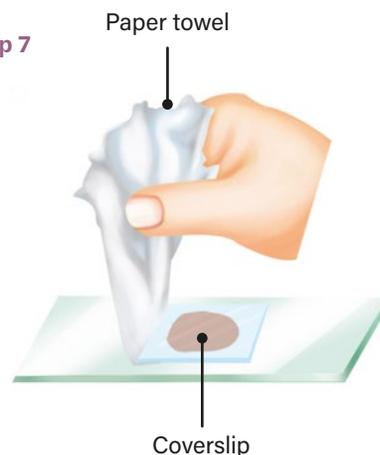
Method

- 1 Watch your teacher demonstrate how to prepare a microscope slide.
- 2 Place one drop of iodine solution in the centre of the microscope slide.
- 3 Using the knife and chopping board, cut a small piece from an onion ring.
- 4 Using your fingernails or tweezers, carefully peel away the membrane from the inner curve of the onion piece.
- 5 Place this membrane on the drop of iodine on the slide. Try to prevent the membrane curling. Place a second drop of iodine solution on top of the onion membrane.

Step 6



Step 7



continues ▶

- 6 Use the blunt dissecting needle to lower a coverslip carefully and slowly over the onion membrane.
- 7 Use a corner of a paper towel to gently soak up any extra liquid that squeezes out from under the coverslip.
- 8 Examine the slide under the microscope. Record your observations.

Questions

- 1 Identify an appropriate question that would be answered by conducting this investigation.
 - A What does a cell look like?
 - B How does using a microscope change the features of an onion that can be seen?
 - C What do onion cells look like?

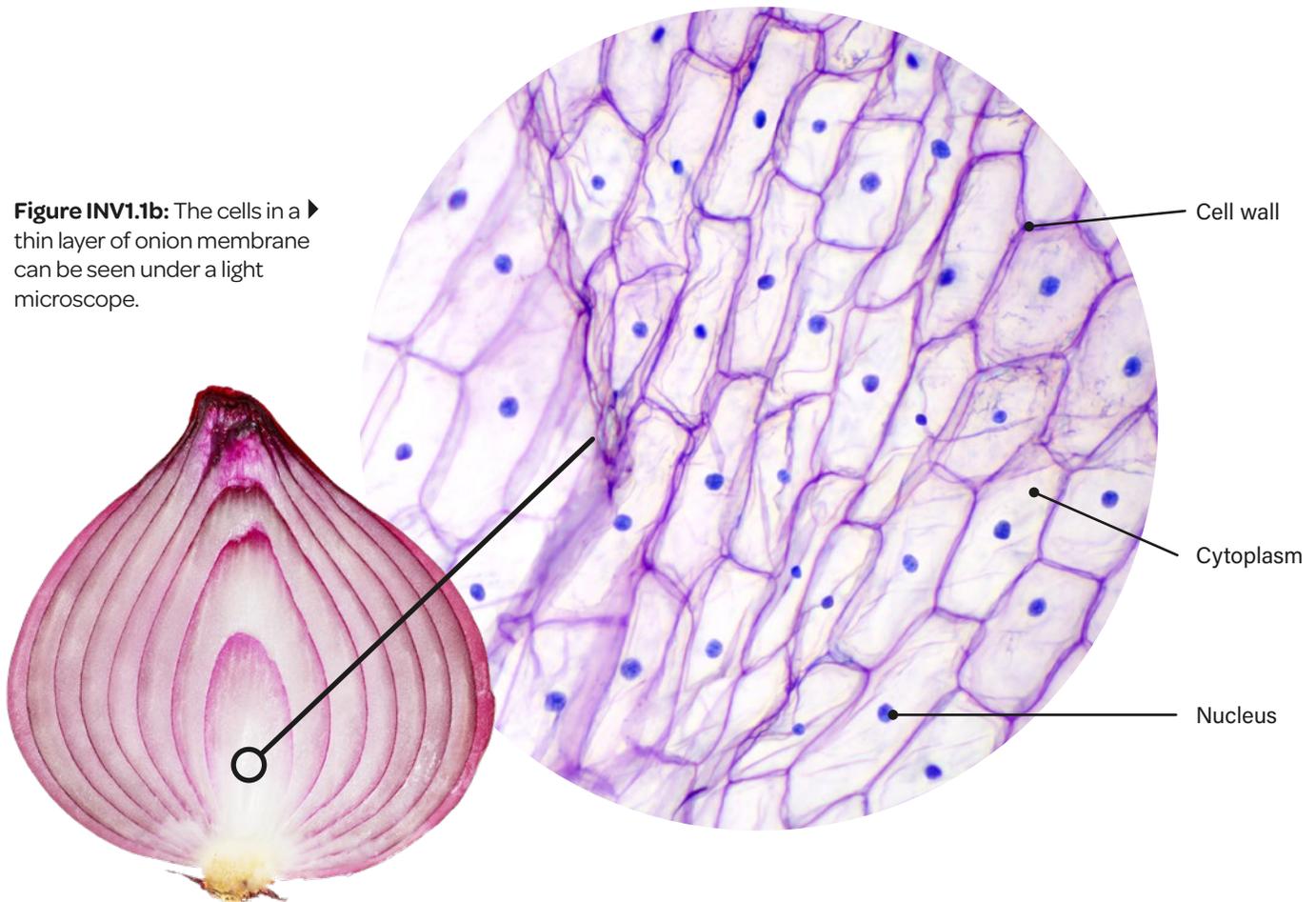
- 2 Why was iodine used in this investigation?
- 3 Describe how you brought your onion slide into focus using the light microscope.
- 4
 - a Draw a scientific diagram of the onion cell as you see it under the microscope.
 - b Record the magnification of the image.
- 5 Consider this investigation. Could you conduct a similar one to view other cells? Construct a scientific question you could investigate to find out more information about cells.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Figure INV1.1b: The cells in a ▶ thin layer of onion membrane can be seen under a light microscope.



Examining cell structures

Inquiry skill: Planning and conducting

Inquiry skill focus: Generating and recording data

A good investigation involves collecting accurate and precise data. The data collection process must be planned to ensure consistency and organisation, including the type of equipment and tools used to take measurements. This can include using laboratory equipment, scientific tables and appropriate scientific diagrams.

Hint 1: What data do you want to record about the cells?

Hint 2: Which method of recording data will most precisely show your observations?

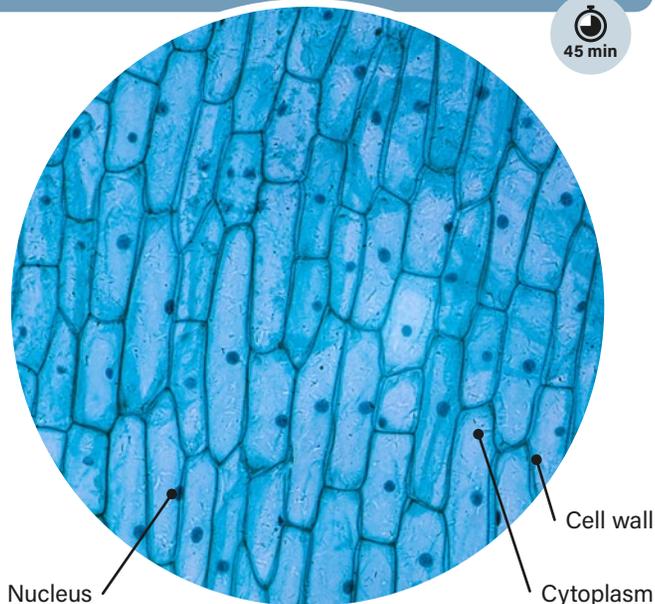


Figure INV1.2: Plant cells at 400x magnification

Aim

To investigate the structures of different cells

Materials

- light microscope
- prepared microscope slides of different cells (cells from animals, plants, fungi and bacteria)

Method

- 1 Copy the results table into your notebook, adding a title.
- 2 Select one prepared slide from each category (cells from animals, plants, fungi and bacteria).
- 3 **a** Place the slide with animal cells under the microscope and observe the cells.
b Record the cell type, magnification and your observations in the results table.

- 4 Draw a cell diagram of the animal cell. *Hints:*
 - Include a heading naming the cell type.
 - Include labels that point out the features of the cell.

- 5 Repeat this process with the prepared slides of plant, fungi and bacteria cells.

Questions

- 1 State three observations you could make about the cells on the slides before they were under the microscope.
- 2 Describe how using the microscope improved your observations of the cells.
- 3 Explain how constructing scientific diagrams improves the precision of your results.
- 4 What is the difference in the size of the cells you observed? Rank the four types of cells from the smallest to the largest.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim).*'

Table INV1.2: Results

Cell type	Magnification	Observations



Observing unicellular organisms

Inquiry skill: Planning and conducting

Inquiry skill focus: Describing ways to minimise risk

When working with glassware and biological materials, it is important to use safe practices by identifying hazards and describing ways to minimise the risks before commencing your investigation.

Hint 1: What materials could cause harm if used incorrectly?

Hint 2: What strategies minimise the chance of harm occurring?

Hint 3: More information about assessing risks in first-hand investigations is available in the Science how-to section on page 237.

Aim

To investigate unicellular organisms in pond water using a microscope

Materials

- disposable pipette
- pond water
- microscope slides
- coverslip
- paper towel
- light microscope

Method

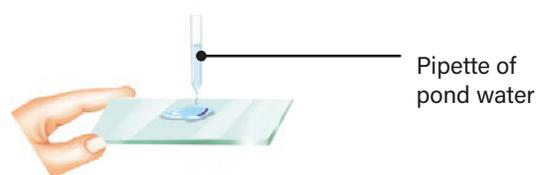
- 1 Use the pipette to place 1 or 2 drops (depending on the size of the drop) of pond water on a clean microscope slide.
- 2 Gently add a coverslip and use the paper towel to wipe away any extra water.
- 3 Put the prepared slide on the microscope and clip it down using the stage clips. (See the 'Scientific equipment' section of Science how-to, page 291.)
- 4 Observe your slide under low magnification. Record your observations.
- 5 Increase the magnification to high and observe the sample again. Record your observations.
- 6 Construct two diagrams to represent what you observed at low and high magnification.



MICROSCOPE SLIDES ARE MADE OF GLASS AND CAN BREAK EASILY. IF YOU CUT YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND SEEK FIRST AID. POND WATER CONTAINS MICROORGANISMS WHICH CAN BE HARMFUL. DO NOT DRINK IT.

▼ **Figure INV1.3:** Steps 1 and 2 of this investigation

Step 1



Step 2



Questions

- 1 Use the questions below to describe and manage three potential risks in this investigation.
 - a Hazards: Identify three things that could harm the person conducting this investigation.
 - b Risks: Decide whether you think there is a low, medium or high chance that each hazard will harm the person conducting this investigation.
 - c Management strategies: What steps can you take to make sure each hazard does not harm the person conducting this investigation?
- 2 Why was a microscope necessary to view these organisms?
- 3 Identify the number of organisms you could see under low magnification.
- 4 Describe what happened as you switched from a lower to a higher magnification.
- 5 Count how many of each organism you saw. Draw a column graph representing the number of organisms in a drop of pond water.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Investigation 1.4A

Investigating respiration

Inquiry skill: Planning and conducting

Inquiry skill focus: Distinguishing between variables

In an investigation, there should be one independent (changed) variable and one dependent (measured) variable. All other variables should be controlled or remain consistent throughout all trials of the investigation. This will ensure that the changed variable is responsible for any changes that are observed or measured. What are the variables in this investigation?

Hint 1: What are we changing and measuring in this investigation?

Hint 2: Explain how you controlled three variables in order to ensure that your investigation remained a fair test.

Hint 3: Refer to step 3, 'Planning and conducting investigations', in the Science how-to, page 238.

Aim

To identify which temperature is the most suitable for yeast respiration

Materials

- 3 × 500 mL empty, plastic, single-use soft-drink or water bottles with lids (or borosilicate reagent bottles)
- 3 sticky labels (or masking tape)
- 10 g yeast
- 25 g sugar
- metric teaspoon
- filter funnel
- 150 mL measuring cylinder
- 3 beakers, large enough to hold more than 100 mL of water each
- 300 mL tap water
- ice
- kettle
- thermometer
- marker pen
- 3 balloons
- small tape measure (2 m or 5 m)
- matches



▲ **Figure INV1.4Aa:** When using a kettle to heat water, do not touch the steam or the boiling water as these substances will burn your skin.

Method

- 1 Copy the results table into your notebook, adding a title.
- 2 Using the sticky labels, label the three bottles: Bottle 1, Bottle 2, Bottle 3.
- 3 Add 2 teaspoons of yeast and 5 teaspoons of sugar to each empty bottle using a filter funnel.
- 4 Prepare three beakers of water:
 - Beaker 1: 100 mL of water at 10 °C
 - Beaker 2: 100 mL of water at 35 °C
 - Beaker 3: 100 mL of water at 60 °C

Use the ice and the kettle to adjust the temperature of the water in the beakers. Measure the water using the measuring cylinder.

- 5 **a** Pour the contents of Beaker 1 into Bottle 1.
b Pour the contents of Beaker 2 into Bottle 2.
c Pour the contents of Beaker 3 into Bottle 3.
- 6 Replace the lids on the three bottles. Shake each bottle to mix the contents. Use the pen to mark the level of the mixture in each bottle.
- 7 Remove the lids of the three bottles. While you hold each bottle, have a classmate stretch a balloon over the mouth of each.
- 8 Use the tape measure to measure the distance the yeast mixture rises every 5 minutes for 30 minutes. Record your observations in the results table.
- 9 Remove the balloon that has expanded to the largest size. Hold the end of the balloon closed so the gas does not escape.
- 10 Have a classmate light a match. Holding the balloon closed, move the end of the balloon close to the flame. Release the gas in the direction of the flame. Record what happens.

continues ►

Table INV1.4A: Results

Bottle	Water temperature (°C)	Growth of yeast mixture (cm)						Observations
		5 min	10 min	15 min	20 min	25 min	30 min	
1								
2								
3								

Questions

- Which of the following is the correct way to measure 1 teaspoon of yeast?
 - Fill the teaspoon most of the way to the top.
 - Fill the teaspoon exactly to the top without going over the top.
 - Heap the teaspoon with yeast.
- Identify the independent and dependent variables of this investigation.
- Describe what you should do to make sure you do not burn yourself when you are pouring boiling water from the kettle.
- Explain how you controlled three variables in order to ensure that your investigation remained a fair test.

- Discuss three ways you measured in the different parts of the investigation to make sure the measurements stayed the same.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'



THE OPEN FLAME OF A MATCH AND BOILING WATER ARE HAZARDS. NEVER LIGHT A MATCH UNLESS INSTRUCTED TO DO SO BY YOUR TEACHER. BE CAREFUL WHEN USING MATCHES AND POURING BOILING WATER. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES.



Figure INV1.4Ab: Yeast comes in different forms.



Energy from food

Inquiry skill: Planning and conducting

Inquiry skill focus: Generating and recording data

A good investigation involves collecting accurate and precise data. The data collection process must be planned to ensure consistency and organisation, including the type of equipment and tools used to take measurements. This can include using laboratory equipment, scientific tables and appropriate scientific diagrams.

Hint 1: What data are you recording in this investigation? Why is a table an appropriate way to record this data?

Hint 2: How does the equipment you are using help to ensure that the results being collected are precise?

Aim

To investigate which foods release the most energy when burnt

Materials

- piece of bread
- selection of other foods (for example, pasta, cheese, potato, apple, broccoli, carrot, meat, fish)
- knife
- test tubes (1 per food item)
- 10 mL measuring cylinder
- water
- retort stand with bosshead and clamp
- thermometer
- Bunsen burner
- 2 heatproof mats
- evaporating basin
- tripod
- gauze mat
- matches
- probe (wooden handle with sharp metallic end) or metal tongs



AN OPEN FLAME IS A HAZARD. BE CAREFUL WHEN USING A BUNSEN BURNER. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES.

Method

- 1 Copy the results table on the next page into your notebook, adding a title and as many rows as needed.
- 2 Cut all the food into pieces of the same size that will fit into a test tube.
- 3 Add 5 mL of water to a test tube. Secure the test tube upright using the retort stand, bosshead and clamp (see Figure INV1.4B).
- 4 Place a thermometer inside the test tube and measure the initial temperature. Record this temperature in the results table.
- 5 On your bench, set up the Bunsen burner on a heatproof mat, with the tripod and the gauze mat. Light the Bunsen burner and turn it to the blue flame.
- 6 Hold the piece of bread with the probe or tongs. Heat the bread over the flame of the Bunsen burner until it ignites (catches on fire).
- 7 Place the piece of burning bread into the evaporating basin on a heatproof mat. Note the highest temperature the water reaches. Record this temperature in the results table.
- 8 Calculate the change in the temperature of the water. (Deduct the initial temperature from the highest temperature.)
- 9 Repeat steps 3–8 with other foods. Ensure you turn off the Bunsen burner at the end of this investigation.

continues ►

Table INV1.4Ba: Results

Food item	Initial temperature (°C)	Highest temperature (°C)	Change in temperature (°C)
Bread			

Table INV1.4Bb: Risk assessment for Investigation 1.4B

Hazard	Risk (low, medium or high)	Strategy

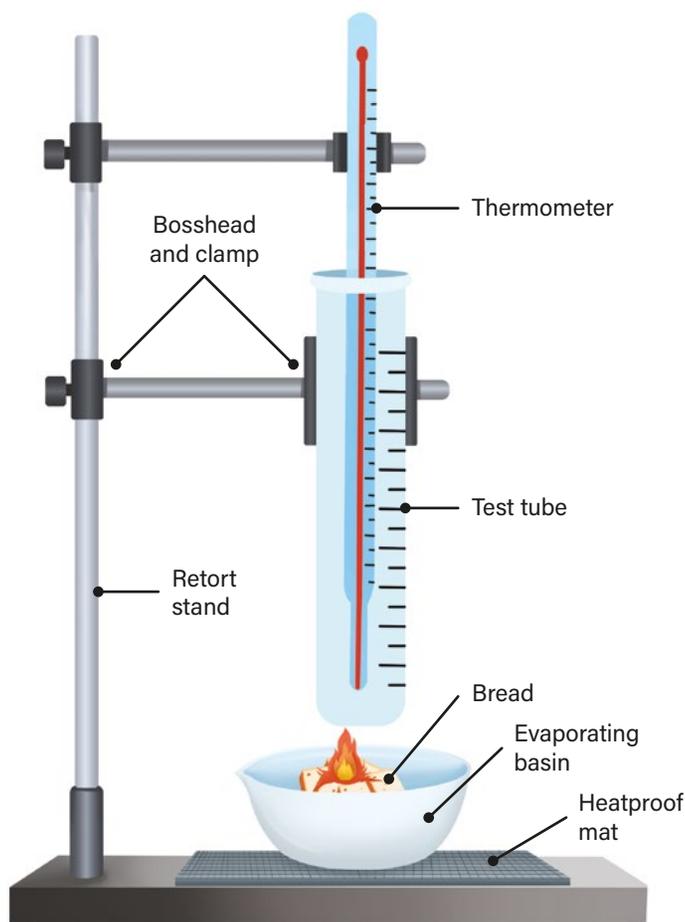
Questions

- 1 Describe the correct process for setting up a Bunsen burner.
- 2 How did using the probe or tongs allow you to safely conduct the investigation while still collecting data?
- 3 Explain how the scientific equipment you used in this investigation allowed you to ensure your results were precise.

- 4 Copy the risk assessment table INV1.4Bb into your notebook.
 - a Identify three things that could go wrong during this investigation. These errors could mean the results are not accurate.
 - b Suggest how these three errors could be avoided if this investigation is repeated.
- 5
 - a State the highest temperature the water reached.
 - b Which food was under the water when you recorded the highest temperature?
 - c Why do you think the water reached the highest temperature for that particular food?

Conclusion

Copy and complete:
 ‘The results show that: *(respond to the aim)*.’



◀ **Figure INV1.4B:** For this investigation, set up the materials as shown in this diagram.

Breathing rate and exercise

Inquiry skill: Communicating

Inquiry skill focus: Identifying scientific terminology

When conducting investigations, it is important to identify and understand scientific terminology relevant to the topic, so that it can be used in the discussion of results and conclusion.

Hint 1: Make a glossary of scientific terms related to the respiratory system.

Hint 2: When answering the follow-up questions, try to use as many glossary terms as possible throughout your responses.

Aim

To investigate the effect of exercise on breathing rate, heart rate, perspiration and body temperature

Materials

- body temperature thermometer
- heart rate monitor (if available)
- watch (or a stopwatch)
- skipping rope

Method

- 1 Copy the results table into your workbook, adding a title.
- 2 Find a partner to work with and an area that is suitable to exercise in.
- 3 Observe your partner's skin tone (redness) (look at their face and arms). Rate their skin tone using a scale of 1–4, where 1 is normal, 2 is slightly red, 3 is red and 4 is very red. Record your rating in the results table in the 'O (rest)' row.
- 4 Observe your partner's level of perspiration. Rate their perspiration level using a scale of 1–4, where 1 is no sweating, 2 is slightly sweating, 3 is sweat building up under the armpits and 4 is extremely sweaty. Record your rating in the results table in the 'O (rest)' row.
- 5 Use the body temperature thermometer to measure your partner's body temperature. Record this information in the results table in the 'O (rest)' row.
- 6
 - a Use the heart rate monitor to count how many times your partner's heart beats in 15 seconds. Record this information in the results table in the 'O (rest)' row.
 - b Use the heart rate monitor to measure your partner's heart rate, which is the number of beats per minute. Record this information in the results table in the 'O (rest)' row.

If you do not have a heart rate monitor, you can measure your partner's pulse by placing your index and third fingers on their neck to the side of their windpipe. Count how many times you feel a pulse in 15 seconds, then multiply by 4 to get the number of heart beats per minute.
- 7
 - a Count how many breaths your partner takes in 15 seconds. Record this information in the results table in the 'O (rest)' row.
 - b Calculate your partner's breathing rate, which is the number of breaths they take in 1 minute. To do this, multiply the number of breaths they take in 15 seconds by 4. Record your partner's breathing rate in the results table in the 'O (rest)' row.
- 8 Your partner exercises vigorously (for example, skipping rope or doing jumping jacks) for 5 minutes.
- 9 While your partner is exercising, measure and record their skin tone, level of perspiration, heart rate and breathing rate every minute. Measure and record their temperature if you have a thermometer that allows you to do this (for example, an infrared thermometer).
- 10 Take these measurements again every minute for 5 minutes after your partner stops exercising.

continues ►

Table INV2.3: Results

Time (minutes)	Skin tone (redness) (1-4)	Perspiration level (1-4)	Body temperature (°C)	Heartbeats in 15 seconds	Heart rate (beats per minute)	Breaths in 15 seconds	Breathing rate (breaths per minute)
0 (rest)							
1							
2							
3							
4							
5 Stop exercise							
6							
7							
8							
9							
10							

Questions

- 1 Describe how your partner’s breathing rate changed throughout the investigation.
- 2 What changes did you observe in your partner’s:
 - a skin tone (redness)?
 - b perspiration level?
 - c body temperature?
 - d heart rate?
- 3 Explain how changes in skin tone, perspiration level and body temperature during and after exercise are linked to each other.
- 4 If you repeat an exercise routine regularly, you become fitter and your heart rate and breathing rate do not rise as high as they did before you exercised regularly. Suggest why this occurs.
- 5
 - a Construct line graphs of your data, showing how the variables changed over time.
 - b Use your graphs to identify the relationship between breathing rate and heart rate.
 - c Suggest a reason for the relationship you identified in Question 5b, considering that the heart is not part of the respiratory system.

Conclusion

Copy and complete:
 ‘The results show that:
 (respond to the aim).’



Figure INV2.3: In this ▶ investigation, work in pairs: one person exercises while the other person makes observations.



Dissecting a heart

Inquiry skill: Questioning and predicting

Inquiry skill focus: Constructing scientific questions

Turn the aim of this investigation into a question that asks about the scientific problem or concept you are investigating. This is called a research question.

Hint 1: Ensure that your question can be investigated scientifically.

Hint 2: Refer to 'Questioning and predicting' in the Science how-to section on page 232.

Aim

To investigate the structure of the heart of a mammal

Materials

- safety glasses
- disposable plastic aprons
- nitrile gloves
- newspaper (or butchers paper)
- dissecting board
- sheep or cow heart
- dissection kit (dissection scissors, blunt forceps and blunt probes)
- pipe cleaners
- pins
- labels
- disinfectant
- camera



WEAR SAFETY GLASSES AND GLOVES. BE CAREFUL WHEN USING CUTTING IMPLEMENTS. DISPOSE OF ALL MATERIALS AS DIRECTED BY YOUR TEACHER. WASH YOUR HANDS AFTER COMPLETING THE INVESTIGATION.

Method

- 1 Place some newspaper on the bench and the dissecting board on top of it.
- 2 Wearing safety glasses, an apron and nitrile gloves, carefully examine the heart. The blood vessels around the outside are the coronary arteries and veins; these take blood to and from the heart muscle.
- 3 Feel either side of the heart. One side should feel thicker than the other. The thicker side is the left, and the smaller and thinner side is the right.
- 4 Look for the blood vessels on the top of the heart. Stick in pipe cleaners or your fingers to see where they lead to.
- 5 Place the heart on the dissecting board with the apex (pointed end) towards you and the right (thinner) side of the heart to your left.



▲ **Figure INV2.4a:** Step 5 of this investigation

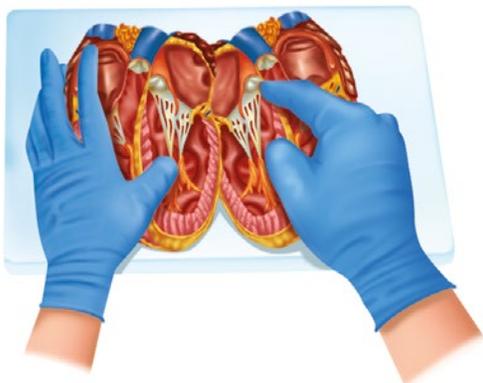
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- 6 Use the dissection scissors to carefully make a cut around the outside of the heart.



▲ **Figure INV2.4b:** Step 6 of this investigation

- 7 You should now be able to open the heart and see inside both the right and left sides.



▲ **Figure INV2.4c:** Step 7 of this investigation

- 8 Carefully examine the inside of the heart. Identify the valves between the atria and ventricles of each side. These are controlled by tendons called *chordae tendineae*, which are commonly known as the 'heartstrings'. Try pulling these.
- 9 Identify the septum; this is the structure that separates the left and right sides of the heart.
- 10 Use the pins and labels to:
- label the structures of the heart: left and right side, atria, ventricles, aorta, vena cava and valves.
 - indicate the direction of oxygenated and deoxygenated blood flow.
- 11 Take a photo of the labelled, dissected heart.
- 12 When you have completed your dissection, carefully clean up and disinfect your work area.

Questions

- Compare the size of the left and the right sides of the heart. Why is there such a size difference?
- Compare the size of the atria and the ventricles. Why is there such a size difference?
- What is the function of the valves in the heart?
 - What might occur if the valves did not function properly?
- What is the function of the septum in the heart?

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Water transport in plants

Inquiry skill: Questioning and predicting

Inquiry skill focus: Making predictions

A key component of first-hand investigations is making a prediction of the outcome of the investigation. You may not know much about the concepts under investigation yet, so sometimes it is okay to make a prediction based on what you already know or have observed. Answer Question 1 before you start this investigation.

Hint 1: Think about how water gets from the soil to the highest leaves.

Hint 2: More information about making predictions is available in the Science how-to section on page 233.

Aim

To investigate how water is transported in plants

Materials

- nitrile gloves
- 3 × 200 mL beakers
- 200 mL water
- food colouring
- knife
- cutting board
- 3 celery sticks, with leaves still attached, cut to 20 cm lengths
- magnifying lens

Method

- 1 Label the three beakers A, B and C.
- 2 **a** Add 100 mL of water to beaker A.
b Add 100 mL of water to beaker B.
c Leave beaker C empty.
- 3 Add enough food colouring to beaker A to make the water a dark colour.
- 4 Using a knife and a cutting board, cut off 2 cm from the bottom of each stick of celery.
- 5 Place one celery stick in each beaker. Leave them to stand overnight.
- 6 The next day, observe the leaves of the three celery sticks. Record your observations in your notebook.

- 7 Wearing nitrile gloves, remove the celery that was in the coloured water (beaker A) and use the knife to slice it crosswise and lengthwise. Use the magnifying lens to observe the pathway of the food colouring.
- 8 In your notebook, draw the celery from beaker A.

Questions

- 1 Predict what you will observe:
 - a** in each of the three sticks of celery in beakers A, B and C after leaving them overnight.
 - b** by using the magnifying glass in step 7 of the method.
- 2 Propose the purpose of beakers B and C.
- 3 Explain what happened to the celery in beaker A in terms of the plant's water transport system.
- 4 **a** Identify the results obtained from beaker C.
b Propose why this happened.
- 5 Describe how water is transported in plants, using key terms, written observations or diagrams from this investigation to support your answer.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'



BE CAREFUL USING A KNIFE. IF YOU CUT YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND SEEK FIRST AID.



Figure INV2.7: Make sure the liquid in beaker A is a dark colour.

Dissecting a flower

Inquiry skill: Communicating

Inquiry skill focus: Preparing representations to communicate findings

Being able to represent findings in effective and appropriate ways is important for communicating science to others clearly and precisely. After conducting this investigation, you should be able to prepare a representation of the parts of a flower to communicate information.

Hint: Refer to step 3 of 'Communicating' in the How-to section on page 257.

Aim

To investigate the physical features of flowering plants

Materials

- safety glasses
- nitrile gloves
- magnifying lens
- 1 large, whole flower (such as a lily or tulip)
- dissecting board
- dissecting kit (dissection scissors and blunt forceps)



WEAR SAFETY GLASSES AND GLOVES. BE CAREFUL WHEN USING CUTTING IMPLEMENTS. DISPOSE OF ALL MATERIAL AS DIRECTED BY YOUR TEACHER. WASH YOUR HANDS AFTER THE INVESTIGATION.

Method

- 1 In groups of 3 or 4, use a magnifying lens to observe the external features of a flower. Record your observations in your notebook.
- 2 Locate both parts of the flower's stamen (the anther and filament). Record your observations in your notebook.
- 3 Record your observations from steps 3a and 3b in your notebook.
 - a Locate all three parts of the flower's pistil (stigma, style and ovary).
 - b Wearing gloves and safety glasses, place the flower on the dissecting board. Using the dissection scissors, cut open the ovary and count the number of eggs inside.

Questions

- 1 Propose why it is important for the anther to be towards the top of the flower.
- 2 Recall how many eggs were inside the plant's ovary. Describe how you could tell they were eggs.
- 3 Explain how pollen moves from the male to the female reproductive parts of the flower.
- 4 Prepare a 3D model of the parts of a flowering plant system using materials supplied in the classroom. Compare your model to the flower in your investigation. Propose which is a better representation for helping you to understand the parts of a flower that enable survival.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim).*'



Figure INV2.8: Use the magnifying lens to closely observe the flower. Remember to wear safety glasses and gloves!

Investigation 3.2



Comparing metals and non-metals

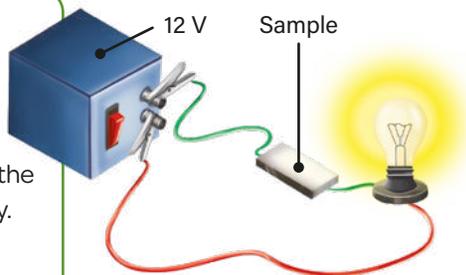
Inquiry skill: Planning and conducting

Inquiry skill focus: Identifying scientific equipment

Before starting a first-hand investigation, it is important to identify the equipment that will allow the investigation to be conducted safely and effectively.

Hint 1: Is the data in this investigation quantitative or qualitative?

Hint 2: What equipment is being used in this investigation to collect data?



ELECTRICITY IS A HAZARD. BE VERY CAREFUL WHEN USING ELECTRICITY.

Figure INV3.2: For this investigation, set up the electric circuit as shown in this diagram.

Aim

To investigate the properties of metals and non-metals

Materials

- selection of samples of metals, non-metals and metalloids (e.g. carbon (graphite), silicon, aluminium, zinc, copper, glass, iron, rubber, sulfur)
- steel sewing needle
- 12 V power supply
- 12 V light bulb
- 3 connecting wires
- alligator clips

Method

- 1 Copy the results table into your notebook, adding a title and as many rows as needed.
- 2 Choose one of the samples. In the results table, record your observations of its appearance (e.g. its colour, how shiny it is).
- 3 Try to bend the sample to test its malleability. Record your observations in the results table.
- 4 Scratch the sample using the steel sewing needle. Is the sample shiny underneath? Record your observations in the results table.

- 5 Connect the electric circuit as shown in Figure INV3.2.
- 6 Switch on the power supply to 12 V. Observe whether the light bulb turns on. If it does, the sample conducts electricity. Record your observations in the results table.

Questions

- 1 In your results table, categorise each of the materials tested in this investigation as a metal or a non-metal.
- 2 What properties did all the metals have in common?
- 3 Were there any properties common to both metals and non-metals?
- 4 Predict the properties of tungsten (metal) and iodine (non-metal).
- 5 a Propose alternate equipment for this investigation that could be used to generate quantitative data with precision.
b Discuss whether the proposed equipment would help you to classify the substances as metals or non-metals.

Conclusion

Copy and complete:

'The results show that: (respond to the aim).'

Table INV3.2: Results

Sample (independent variable)	Appearance	Malleable (y/n)	Scratchable (y/n)	Conducts electricity (y/n)	Predict: metal or non-metal?

Investigation 3.3

Investigating the different properties of a compound and one of its elements

Inquiry skill: Planning and conducting

Inquiry skill focus: Describing ways to minimise risk

When conducting any first-hand investigation, it is important to use safe practices to minimise the risk of harm. Before you begin, identify potential hazards and put in place strategies to minimise the chance of accidents or harm occurring in the laboratory.

Hint 1: What materials in this investigation could cause harm if used incorrectly?

Hint 2: What strategies minimise the chance of harm occurring?

Hint 3: More information about assessing risks in first-hand investigations is available in the Science how-to section on page 237.

Aim

To investigate how the properties of a compound are different from the properties of the elements from which it is made

Materials

- safety glasses
- Bunsen burner
- heatproof mat
- tripod
- pipeclay triangle
- crucible and lid
- 5 cm magnesium ribbon
- matches
- crucible tongs



AN OPEN FLAME IS A HAZARD. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES.

MAGNESIUM RIBBON IS A HAZARD. IT IS FLAMMABLE AND REACTIVE. BE EXTREMELY CAREFUL. NEVER LOOK DIRECTLY AT A BURNING MAGNESIUM RIBBON.

Method

- 1 Set up the Bunsen burner, mat, tripod, pipeclay triangle and crucible as shown in Figure INV3.3 on the next page.
- 2 Look closely at the magnesium ribbon. Record your observations (e.g. its colour, lustre and feel) in your notebook.
- 3 Place the magnesium ribbon inside the crucible and put on the lid.
- 4 Light the Bunsen burner. Heat the crucible containing the magnesium. Using tongs, lift the lid every 5–10 seconds to ensure enough air is in the crucible. **Do not look directly at the magnesium ribbon.**
- 5 The heated magnesium will combine with the oxygen in the air to create magnesium oxide, a compound. After the magnesium has finished reacting, observe the magnesium oxide. Record your observations about its physical properties in your notebook.

Questions

- 1 Copy the risk assessment table into your notebook. Write your answers to the following questions in the table.
 - a **Hazards:** Identify four things that could harm the person conducting the investigation.
 - b **Risks:** Decide whether you think there is a low, medium or high chance that each hazard will harm the person conducting the investigation.
 - c **Management strategy:** Describe ways to minimise the risk that each hazard presents to the person conducting this investigation.
- 2 Describe how the appearance of the magnesium differed from that of the magnesium oxide.
- 3 Explain the purpose of regularly lifting the crucible lid.

Conclusion

Copy and complete:

'The data shows that ... (respond to the aim).

This makes sense because ...'

Figure INV3.3:

For this investigation, set up the materials as shown in this diagram.

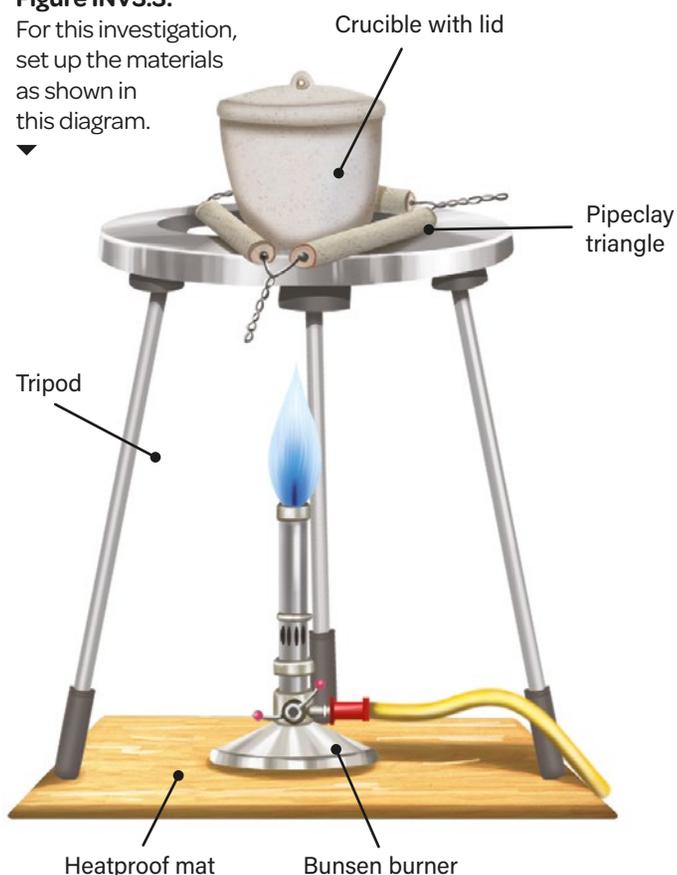


Table INV3.3: Risk assessment for Investigation 3.3

Hazard	Risk (high, low, medium)	Management strategy

Separating a mixture

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Identifying data

When conducting investigations, it is important to identify the type of data that can be collected. It can then be recorded, processed and displayed in an organised way, which will lead to the finding of the investigation. Read the method for this investigation and determine the type of data you will be collecting.

Hint 1: Quantitative data is data that can be counted, measured or represented by numbers.

Hint 2: Qualitative data is data with qualities or characteristics that can be observed and described.

Aim

To investigate the process of separating a mixture of salt and water

Materials

- electronic balance
- 10–15 g of sodium chloride (table salt)
- 150 mL beaker
- approx. 100 mL of tap water
- evaporating dish
- Bunsen burner
- heatproof mat
- tripod
- pipeclay triangle
- matches

Method

- 1 Weigh 10–15 g of salt into the 150 mL beaker.
- 2 Add about 100 mL of water to the beaker. Stir until all of the salt is dissolved.
- 3 Pour some of the salt solution into an evaporating dish so it is about half full.
- 4 Set up the apparatus as shown.
- 5 Heat the salt-water solution for a few minutes until the water has all evaporated.
- 6 Observe the salt remaining in the dish. Record your observations.



AN OPEN FLAME IS A HAZARD. USE WITH CAUTION. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES.

Questions

- 1 Compare the appearance of the salt at the end of the investigation to the salt at the beginning. Describe how it is different.
- 2 Describe what happened to the water during the experiment.
- 3 Explain how this investigation confirms that salt water is a mixture.
- 4 Propose other ways to separate a mixture of salt and water.
- 5 a Describe how this investigation could be modified to collect quantitative data.
b Identify additional equipment that would be required to collect precise measurements.
- 6 Calculate the mass per cent (%m/m) of the solution you made in step 2 of the method.

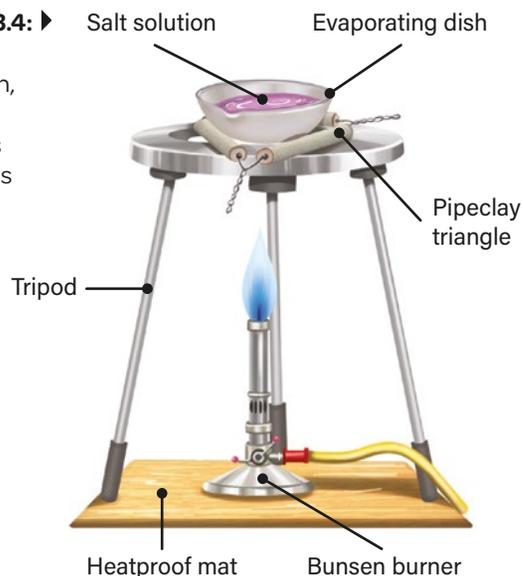
Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Figure INV3.4: ▶ Salt solution Evaporating dish

For this investigation, set up the materials as shown in this diagram.





Comparing the properties of elements, compounds and alloy mixtures

Inquiry skill: Planning and conducting

Inquiry skill focus: Generating and recording data

A good investigation involves collecting accurate and precise data. The data collection process must be planned to ensure consistency and organisation, including the type of equipment and tools used to take measurements. This can include using laboratory equipment, scientific tables and appropriate scientific diagrams.

Hint 1: Does the equipment used in this experiment let you collect exact values?

Hint 2: Is the results table suitable for collecting detailed information?

Hint 3: Refer to the Science how-to section on page 220.

Aim

To investigate and compare the properties of substances in different forms: elements, compounds and alloy mixtures

Materials

- safety glasses
- samples: several trios of substances in pure, compound and alloy form (10 mL of liquid sample, 5 g of granular sample, 1 piece of solid sample); for example:
 - copper metal, copper sulfate, brass
 - graphite, ethanol, carbon steel
 - iron metal, iron oxide (pigment), cast iron
- 12 V power supply
- 12 V light bulb
- 3 connecting wires
- alligator clips
- 2 paperclips (electrodes)
- watch glass (for granular samples)
- spatula
- 10 mL measuring cylinder
- 100 mL beakers (for water and each liquid sample)
- 50 mL tap water

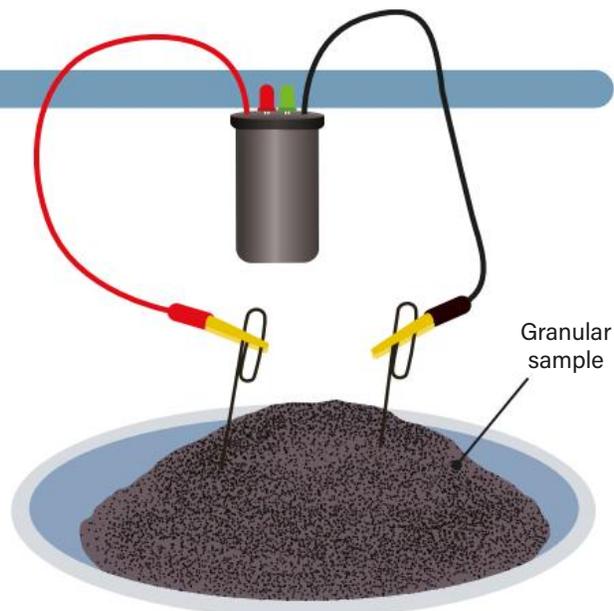
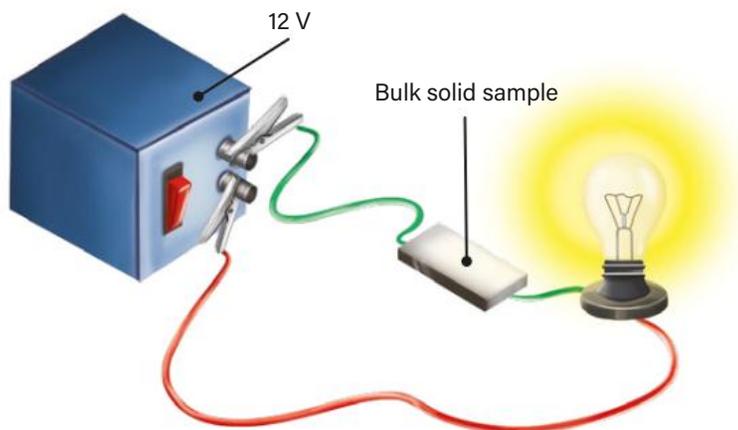


COPPER SULFATE IS A TOXIN AND IS HARMFUL TO EYES. WEAR SAFETY GLASSES. DO NOT POUR COPPER SULFATE DOWN THE DRAIN. YOUR TEACHER WILL TELL YOU HOW TO DISPOSE OF THIS SUBSTANCE.

Method

- 1 Copy the results table (on the next page) into your notebook, adding a title and as many rows as needed. You can modify the results table to suit the samples you will be testing. This may make it easier to identify trends in the data you collect. An example has been provided in the table to help you.
- 2 Choose one of the trios of substances.
- 3 Conduct the following investigations to determine the properties of each of the three substances. Record your observations in the results table.
 - a **Appearance:** What does the substance look like? Observe its colour, lustre (shine) and physical state (solid, liquid or gas).
 - b **Malleability:** Can the substance be bent and shaped? For bulk solid samples, try to bend the sample. Is the substance malleable (can you bend and shape it)? Is it brittle (does it break when you try to bend it)?
 - c **Hardness:** How hard is the substance? Scratch the surface of the sample with the other solid samples. Record which samples leave a scratch on which substances.
 - d **Conductivity:** Does electricity flow through the substance? To test this, connect the electric circuit as shown in Figure INV3.5 (on the next page). Turn on the power supply to 12 V. Test each substance as instructed below. Observe whether the light bulb turns on. If it does, the substance conducts electricity.
 - i **Bulk solid sample:** Connect the alligator clips to either side of the sample to complete the circuit.

continues ►



- ii **Granular solid sample:** Connect each alligator clip to an unfolded paperclip. Insert each paperclip into the powder sample, making sure the paperclips do not touch.
 - iii **Liquid sample:** Connect each alligator clip to an unfolded paperclip. Insert each paperclip into the liquid sample. Make sure the paperclips do not touch each other or the sides of the beaker.
- e **Solubility:** Can the substance be dissolved in liquid? Place the solid sample, a spatula full of granular sample or 10 mL of liquid sample into the beaker of water. Observe whether the sample dissolves or not.

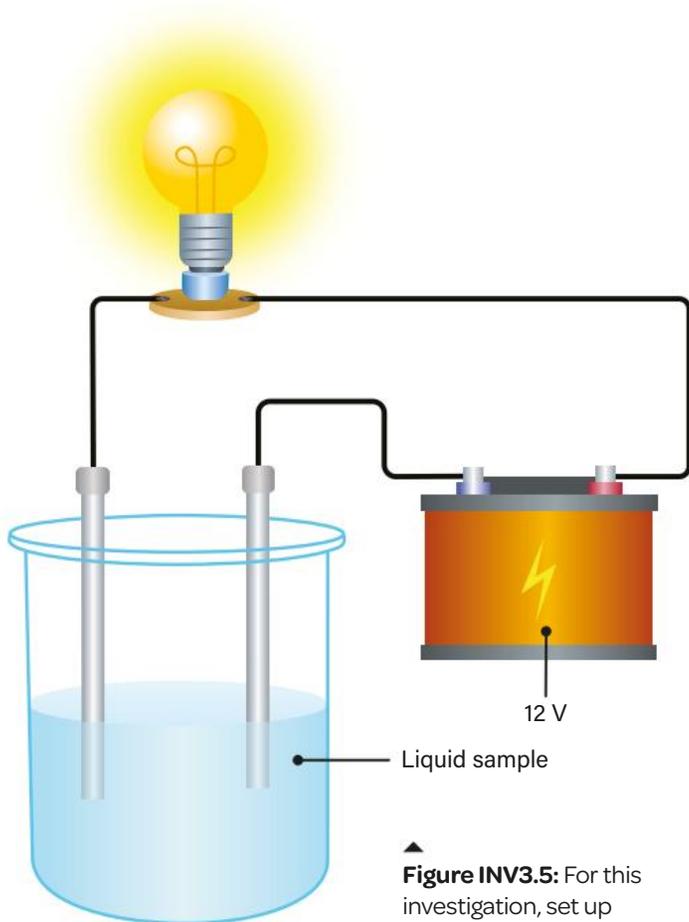


Figure INV3.5: For this investigation, set up the materials as shown in these diagrams.

Questions

- 1 Identify any trends in the data you have collected.
- 2 Describe any unexpected results. Why were these results not what you expected?
- 3 Propose alternative equipment that could be used to collect more precise data.
- 4 Explain how the equipment proposed in Question 3 will help you to compare properties as mentioned in the aim.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Table INV3.5: Results

Element	Form	Appearance	Malleability	Hardness	Conductivity	Solubility
Copper	Pure element (e.g. copper wire)					
	Compound (e.g. copper sulfate)					
	Alloy (e.g. brass)					



Making a molecular modelling kit

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Analysing scientific models

Scientific models are useful in helping us to represent what things look like at the atomic level. But we also need to recognise how these models can be limited. For this reason, we analyse scientific models to evaluate their effectiveness in simulating what is happening in the real world.

Hint 1: Think about what the model is trying to replicate.

Hint 2: What does the model replicate well? What are its weaknesses?

Aim

To make a molecular modelling kit that can be used by Year 8 students to represent a range of three-dimensional models of molecular elements and molecular compounds

Materials

- soft, jellied lollies or mini marshmallows of six different colours (a few of each colour)
- 1 index card
- textas (colours that match the lolly colours)
- 20 toothpicks
- snap-lock bag or small container (to contain your kit)

Method

- 1 Copy the results table into your notebook and complete Question 1 before you begin making your kit.
- 2 Collect your materials. Choose which colour lolly will represent atoms for each type of element in this investigation.
- 3 On the index card, use coloured textas to make a key for your modelling kit, labelling the lolly colour that represents each element.
- 4 Construct a model to represent the first substance in the results table, using the colours according to your key and toothpicks to join the 'atoms'.
- 5 Construct a three-dimensional sketch of your model in the results table.



FOOD OR DRINKS SHOULD NEVER BE HANDLED OR CONSUMED IN THE LABORATORY. IF THE INTENTION IS TO EAT THE LOLLIES, WEAR GLOVES AND CARRY OUT THE ACTIVITY IN A PLACE OTHER THAN A LABORATORY CLASSROOM.

- 6 Repeat steps 4 and 5 for the rest of the substances in the results table.

Hint: Some structures contain double and triple joins between atoms. How will you use the toothpicks to represent this?

Questions

- 1 Complete the first three blank columns of the results table. Hydrogen gas has been done for you as an example.
 - a Identify whether each substance in the results table is an element or a compound.
 - b Identify how many of each type of atom and the total atoms in each molecule.
 - c Predict the structural formula of each molecule. Check your predictions using the internet.
- 2 Consider your tetrachloromethane model. Did it lay flat on the table, or was it more three-dimensional? Propose which is the most accurate way to represent the molecule. Provide a reason.
- 3 Explain the benefits of using molecular models to represent elemental molecules and compounds.
- 4
 - a Propose a limitation of the models related to the size of the lollies.
 - b Propose any other weaknesses related to your molecular modelling kit.
 - c Propose ways to improve this investigation to address the weaknesses in the models.
- 5 Investigate online other molecules that are made up of the elements in this investigation – for example, glucose ($C_6H_{12}O_6$) – and use your molecular modelling kit to construct a model.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

continues ►

Table INV3.6: Results

Substance	Chemical formula	Element or compound	Number of atoms in molecule	Predicted structural formula	Labelled sketch of 3D lolly model (in colour)
Hydrogen gas	H ₂	Element	Hydrogen = 2 Total = 2	H – H	
Water	H ₂ O				
Oxygen gas	O ₂				
Ozone	O ₃				
Carbon dioxide	CO ₂				
Nitrogen gas	N ₂				
Ammonia	NH ₃				
Chlorine gas	Cl ₂				
Tetrachloromethane	CCl ₄				
Sodium chloride*	NaCl		n/a	n/a	

*This is not a molecule. Rather, it is a three-dimensional lattice with a repeating pattern.



◀ **Figure INV3.6:** Atoms of different elements can be represented by coloured lollies when making molecular models.



Modifying metals

Inquiry skill: Planning and conducting

Inquiry skill focus: Distinguishing between variables

In an investigation, there should be one independent (changed) variable and one dependent (measured) variable. All other variables should be controlled, or remain consistent, throughout all trials of the investigation. This will ensure that the changed variable is responsible for any changes that are observed or measured. What are the variables in this investigation?

Hint 1: What are we changing and measuring in this investigation?

Hint 2: Explain how you controlled three variables to ensure your investigation remained a fair test.

Hint 3: Refer to step 3 of 'Planning and conducting investigations' on page 238 of the Science how-to section.

Aim

To investigate how different heating and cooling techniques alter the properties of metals

Materials

- 4 identical, sharp sewing needles
- wooden peg
- Bunsen burner
- heatproof mat
- matches
- 100 mL beaker, filled with cold water
- pliers

Method

- 1 Copy the results table into your notebook, adding a title.
- 2 Stick one of the sewing needles into the wooden peg; the eye of the needle should be in the jaws of the peg. This is needle A.
- 3 Hold needle A over the blue flame of the Bunsen burner until the whole needle is red hot. Avoid exposing the peg to the flame. Then allow the needle to cool slowly in the air.
- 4 Mount needle B into the wooden peg and hold it over the blue flame until it is red hot. Remove from the flame and immediately put the needle into a 100 mL beaker filled with cold water.



AN OPEN FLAME IS A HAZARD. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES.

- 5 For needle C, repeat the process as for needle B. Then, dry and rewarm needle C over the orange flame of the Bunsen burner. Make sure no part of the needle becomes red hot. Then, allow the needle to cool in the air.
- 6 Needle D is your control.
- 7 Use the pliers to bend each needle. Record the properties you observe (e.g. hardness and malleability) in the table in your notebook.

Table INV3.7: Results

Needle	Treatment	Hardness	Malleability	Additional observations
A				
B				
C				
D				

Questions

- 1 **a** Which metal treatment (A, B or C) resulted in the strongest needle?
b Explain these results.
- 2 Explain why the original needle is suitable for its intended purpose (sewing).
- 3 **a** Without using the internet, make a list of common items made from metal that you think may have been modified by heat treatments.
b Do an online search to see if your list from part a is accurate.
c What interesting things did you learn from part b?
- 4 Identify the variables in this investigation:
a independent. **b** dependent. **c** controlled.

Conclusion

Copy and complete:

'The results show that: (respond to the aim).'

Investigation 4.1

Observing physical and chemical changes

TEACHER DEMONSTRATION

Inquiry skill: Planning and conducting

Inquiry skill focus: Identifying scientific equipment

Before starting a first-hand investigation, it is important to identify the equipment that will allow the investigation to be conducted safely and effectively. As you watch this demonstration, identify the equipment used for each test that is conducted and record it in the results table.

Hint 1: You may choose to sketch in your notebook, and label, the equipment that is new to you, for future reference.

Hint 2: For help, refer to the 'Using scientific equipment' section of the Science how-to on page 287.

Aim

To investigate physical and chemical changes

Materials

- Bunsen burner
- tripod
- matches
- evaporating basin
- teaspoon
- 3 test tubes
- vinegar
- mixture of sand and iron filings
- water
- brass tongs
- micro test tube iodide solution
- heatproof mat
- gauze mat
- 3 popsticks
- 3 x 10 mL measuring cylinder
- bicarbonate of soda
- magnet
- Petri dish
- Alka-Seltzer tablet
- 5 cm magnesium ribbon
- 1 M hydrochloric acid
- 5 drops of 0.1 M sodium iodide solution
- 1 drop of 0.05 M lead nitrate solution



STUDENTS OBSERVING SHOULD BE AT LEAST 2 METRES FROM THE DEMONSTRATION, OR WEAR LABORATORY COATS AND SAFETY GLASSES, AND HAVE THEIR HAIR TIED BACK.

LEAD IS A TOXIN AND SHOULD NOT GO DOWN THE SINK. YOUR TEACHER WILL DISPOSE OF LEAD IN A HAZARDOUS WASTE CONTAINER.

Method

- 1 Copy the results table into your notebook, adding a title.
- 2 Your teacher will set up the Bunsen burner on the heatproof mat, with the tripod and gauze mat.
- 3 They will use the Bunsen burner to burn the popsticks above the evaporating basin.
- 4 Observe as they add 1 teaspoon of bicarbonate of soda to a test tube and pour 5 mL of vinegar into it.
- 5 Your teacher will pass the magnet back and forth over the mixture of sand and iron filings (in the sealed Petri dish).
- 6 Your teacher will add one quarter of an Alka-Seltzer tablet to 5 mL of water in another test tube.
- 7 Your teacher will add the piece of magnesium ribbon to 5 mL of acid in a test tube, using brass tongs. Observe closely. They will touch the bottom of the outside of the test tube.
- 8 Your teacher will add 5 drops of sodium iodide to a micro test tube, followed by a drop of lead nitrate.
- 9 Record all of your observations. Explain why you categorised changes as physical or chemical.

Questions

- Describe the difference between a physical change and a chemical change.
- Identify four observations from your results table which indicate that the change was a chemical change.
- Identify which of the changes you observed can be easily reversed. Provide a reason.
 - Determine if it was a physical change or a chemical change.
- List the equipment in order based on the level of risk they pose, from least to greatest.
 - Compare your list with a classmate's list and discuss.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Table INV4.1: Results

Substances	Equipment	Observations	Type of change	Explanation
Popsticks and fire				
Baking soda and vinegar				
Magnet, sand and iron				
Alka-Seltzer and water				
Magnesium and acid				
Sodium iodide and lead nitrate				

Figure INV4.1: Bubbles are produced when vinegar and baking soda react. Is this a physical change or a chemical change?





Burning steel wool

TEACHER DEMONSTRATION

Inquiry skill: Evaluating

Inquiry skill focus: Identifying investigation errors and assumptions

Errors or assumptions in an investigation will cause you to record a value or observation that is higher or lower than the true value. Errors can be caused by numerous things, such as faulty equipment, an experimental flaw or changing environmental conditions. Unidentified errors can lead to assumptions about the investigation results. Scientists aim to minimise errors, but for errors that cannot be eliminated, it is important that they are identified so we can understand how they may impact the results.

Hint 1: Review the Science how-to section on page 249.

Hint 2: What assumptions are being made in this investigation? Can the method be modified to minimise their impact?

Aim

To investigate what occurs when steel wool is burnt

Materials

- steel wool pad, cleaned with acetone
- watchglass
- brass tongs
- electronic balance
- evaporating basin
- 9 V battery

Figure INV4.2: ▶

Does steel wool change physically or chemically when burnt?



STUDENTS OBSERVING SHOULD BE AT LEAST 2 M FROM THE DEMONSTRATION, OR WEAR LABORATORY COATS AND SAFETY GLASSES, AND HAVE THEIR HAIR TIED BACK.

Method

- 1 Your teacher will place some of the steel wool in the watchglass on the electronic balance. Record the total mass in your notebook.
- 2 Your teacher will place the steel wool in the evaporating basin. Record the total mass in your notebook.
- 3 Your teacher will touch the battery terminals to the steel wool, causing it to burn. This will continue until all of the wool is completely burned into ash or powder.
- 4 Record the current mass of the evaporating dish and steel wool. Calculate the current mass of the steel wool alone.

Questions

- 1 a Identify the assumption made in step 3 of the method.
b Describe how the final mass will be impacted if some of the steel wool is left unreacted.
c Propose and describe a way to address this assumption, to prevent it from causing an error in the final mass recorded.
- 2 Identify whether burning steel wool causes a physical change or a chemical change. Justify your answer.
- 3 Describe what happened to the mass of the steel wool. Refer to the data you recorded.
- 4 Explain what happened to the steel wool. Make reference to particle theory.

Conclusion

Copy and complete:

'The results show that: (respond to the aim).'



Law of conservation of mass

Inquiry skill: Planning and conducting

Inquiry skill focus: Generating and recording data

A good investigation involves collecting accurate and precise data. The data collection process must be planned to ensure consistency and organisation, including the type of equipment and tools used to take measurements. This can include using laboratory equipment, scientific tables and appropriate scientific diagrams.

Hint 1: How does the equipment used in this experiment let you collect exact values?

Hint 2: Which method of recording data will keep your data organised?

Hint 3: Refer to the Science how-to section on page 220.

Aim

To observe the mass of reactants before, during and after a chemical reaction

Materials

For each group:

- 2 × 10 mL measuring cylinders (or plastic pipettes)
- 10 mL of 0.1 M sodium sulfate solution
- 100 mL conical flask and stopper
- electronic scales (that weigh masses to at least two decimal places)
- string
- micro test tube
- 20 drops of 0.1 M barium chloride solution



BARIUM IS TOXIC AND SHOULD NOT GO DOWN THE SINK. FOLLOW THE WASTE DISPOSAL INSTRUCTIONS GIVEN BY YOUR TEACHER.

Method

- 1 Copy the results table into your notebook, adding a title and as many rows as needed.
- 2 Working in groups, use a measuring cylinder to measure 10 mL of sodium sulfate solution into a conical flask. Place the flask on the scales.
- 3 Tie the string around the micro test tube.
- 4 Measure 20 drops of barium chloride solution into a micro test tube.
- 5 Carefully lower the micro test tube into the conical flask. Make sure the two solutions do not mix.
- 6 Place the stopper on the flask, using it to pinch the string to hold the test tube upright. Record the mass in the 'before reaction' column of the results table.
- 7 Tilt the flask just enough to allow the solutions to mix. Observe. Re-weigh and record the mass in the 'during reaction' column of the results table.
- 8 Tilt the flask again and swirl the solutions together for 10 seconds, or until the reaction is complete. Re-weigh and record the mass in the 'after reaction' column of the results table.
- 9 Calculate the change in mass and write this in the results table.
- 10 Share your results with other groups in the class. Add the other groups' results to your results table.

Table INV4.3: Results

Class results	Mass of substance before reaction (g)	Mass of substance during reaction (g)	Mass of substance after reaction (g)	Change in mass (g)
Student group 1				
Student group 2				

continues ►

Questions

- 1 **a** Sketch a diagram of how to set up the materials for this investigation. Label the diagram.
 - b** Annotate the diagram to include safety precautions and instructions on how chemical waste should be managed.
- 2 The two solutions of sodium sulfate and barium chloride react to form a solid (barium sulfate) and a liquid (sodium chloride).
 - a** Describe the observations in this reaction that indicate a chemical change has occurred.
 - b** Identify the white product of the reaction.
 - c** Construct a word equation to represent this reaction.
- 3 **a** Describe the purpose of having a stopper on the flask throughout the reaction.
 - b** Propose how the results may have been different without the stopper.

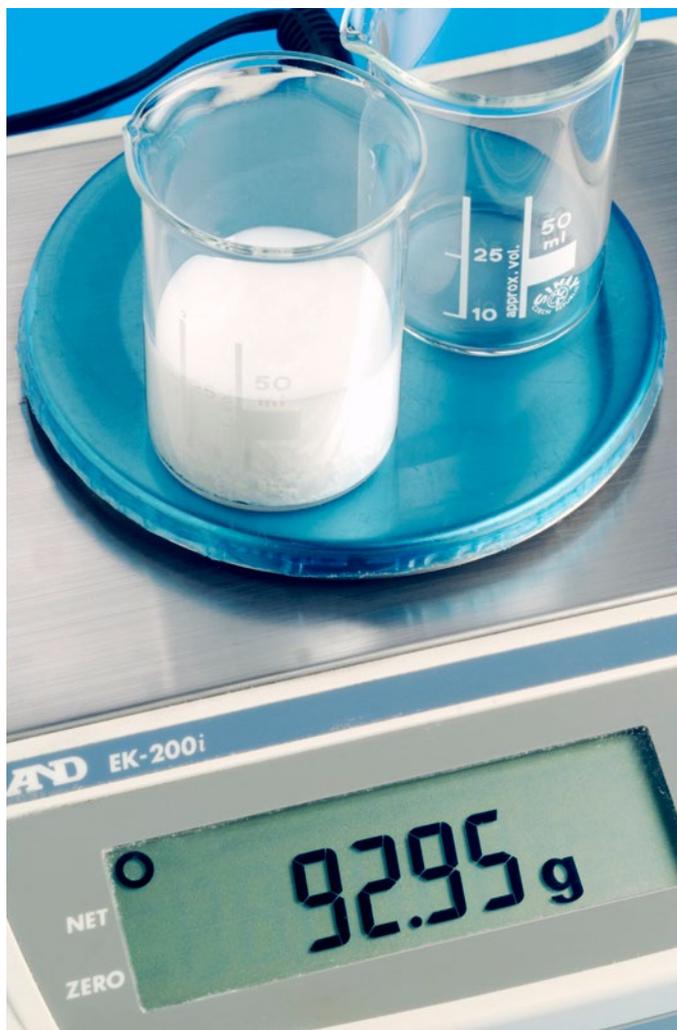
- 4 **a** Explain the benefits of sharing class results, in terms of accuracy and precision of data.
 - b** Discuss the difference between sharing class results and simply conducting more trials within the same group.
 - c** Propose how you could increase the precision of the investigation.
- 5 Explain any variations (or lack of variations) in the different groups' results.
- 6 Justify, with reference to scientific theory, how it is possible that new substances formed, yet there was no increase in mass.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Figure INV4.3: If a reaction forms new substances, why is there no increase in mass?





Identifying gases produced in chemical reactions

Inquiry skill: Evaluating

Inquiry skill focus: Supporting findings with evidence

The data and observations generated and processed in an investigation should always be explained in the discussion of a scientific report using scientific knowledge (see the Science How-to on page 260).

Hint 1: Think about the scientific concepts that are important for the investigation.

Hint 2: Make inferences based on the data and use them to suggest the key findings.

Hint 3: Make links between the key finding and scientific evidence, such as your observations, inferences and the properties of gases.

Aim

To conduct tests to confirm the type of gas produced in a series of chemical reactions

Materials

For each group:

- safety glasses
- nitrile gloves
- 5 x small test tubes
- test tube rack
- 10 mL measuring cylinder
- 10 mL 3% hydrogen peroxide (H_2O_2)
- small spatula (micro spoon)
- 0.3–0.5 g (pea-size scoop) manganese dioxide (MnO_2)
- matches
- long wooden splint
- 10 mL 1 M hydrochloric acid (HCl)
- 3 cm strip magnesium (Mg)
- 2 mL 2 M sodium hydroxide (NaOH)
- 1 g (pea-size scoop) ammonium chloride (NH_4Cl)
- 250 mL beaker
- 100 mL hot water (approx. 80 °C using urn or kettle)
- tongs
- 1 x strip red litmus paper (damp)
- 10 mL lime water (CaOH solution)
- 10 mL vinegar (5% acetic acid)
- large spatula



H_2O_2 , MnO_2 , HCl, NaOH, NH_4Cl , HOT WATER AND FLAMES ARE ALL HAZARDOUS. WEAR SAFETY GLASSES AND GLOVES DURING THIS INVESTIGATION. FUMES CAN BE HAZARDOUS; DO NOT INHALE. POINT TEST TUBE OPENINGS AWAY FROM YOURSELF AND OTHERS TO AVOID EXPOSURE TO THE GAS PRODUCED. DISPOSE OF ALL SUBSTANCES AS DIRECTED BY YOUR TEACHER.

- 5 g (1 scoop) sodium hydrogen carbonate (NaHCO_3)
- test tube stopper with delivery tube

Tips

- Rinse and dry the measuring cylinder and spatulas between each use.
- The splint should be long enough to be used for Parts A, B and C of the investigation.

Method

Part A: Testing for oxygen gas

- 1 Copy the results table, adding a title.
- 2 Place a test tube in a test tube rack.
- 3 Use a measuring cylinder to measure 10 mL of 3% H_2O_2 into the test tube.
- 4 Using a small spatula, carefully add a pea-size amount of MnO_2 to the H_2O_2 .
- 5 Meanwhile, light the wooden splint and let it burn for a few seconds, then blow it out so the tip is glowing (not burning).
- 6 While the reaction is bubbling, quickly insert the glowing splint into the test tube (do not submerge in reaction solution) and record your observations.

Part B: Testing for hydrogen gas

- 1 Place a test tube in a test tube rack.
- 2 Use a measuring cylinder to measure 10 mL of 1 M HCl into the test tube.
- 3 Carefully add the strip of magnesium to the test tube.
- 4 Meanwhile, light the wooden splint and carefully hold the flame over the mouth of the test tube. Record your observations.
- 5 Hold the test tube in your hand and record your observations.

continues ►

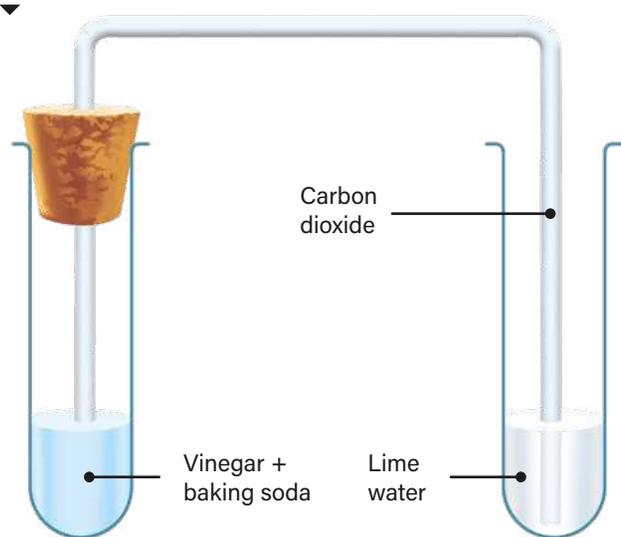
Part C: Testing for ammonia gas

- 1 Place the test tube in a test tube rack.
- 2 Use a measuring cylinder to measure 2 mL of 2 M NaOH into the test tube.
- 3 Using a small spatula, carefully add a pea-size amount of NH_4Cl to the NaOH and swirl.
- 4 Meanwhile, prepare a bath of about 100 mL hot water in a 250 mL beaker.
- 5 Place the test tube in the hot-water bath for 2 minutes.
- 6 Using tongs, hold a damp strip of red litmus paper over the mouth of the test tube. Record the results.
- 7 *Optional:* Light the wooden splint and carefully hold the flame over the mouth of the test tube. Record the results.

Part D: Testing for carbon dioxide gas

- 1 Place two test tubes in a test tube rack.
- 2 Use a measuring cylinder to measure 10 mL of lime water into one test tube, and 10 mL of vinegar into the other. (Rinse the measuring cylinder between measurements.)

Figure INV4.5: Set-up for Part D



- 3 Using a large spatula, add a scoop of NaHCO_3 to the test tube with vinegar and QUICKLY place the stopper and delivery tube over the test tube, as shown in Figure INV4.5.
- 4 Insert the other end of the delivery tube into the lime water. Record your observations.

Questions

- 1 Identify two observations that indicate a chemical change occurs when carbon dioxide is bubbled through lime water.
- 2 Review your observations from Part B, step 5.
 - a Explain what your observation indicates about the flow of energy during the reaction.
 - b Propose how this observation could be measured with precision, including the required equipment and units of measurement.
- 3 Discuss the findings of each part of the investigation with reference to observations, inferences and scientific theory. Support your findings using practical and theoretical evidence.
- 4 Based on the reacting substances and your findings:
 - a Predict the products of each of the four reactions.
 - b Construct a word equation for each of the four reactions based on your predictions in part a.
 - c Conduct an online search to evaluate the accuracy of your word equations. Make corrections as needed.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Table INV4.5: Results

Part	Reactants	Observations	Inference	Gas produced?
A	hydrogen peroxide + manganese dioxide			
B	hydrochloric acid + magnesium			
C	sodium hydroxide + ammonium chloride			
D	sodium hydrogen carbonate + vinegar			

Exothermic and endothermic reactions

Inquiry skill: Evaluating

Inquiry skill focus: Describing types of errors

Investigations are never perfect. There are often errors in the method or equipment that impact the results and must be identified. Acknowledging and describing various types of errors helps to evaluate the reliability of your results and allows improvements to be made in future investigations. (See step 2 of 'Evaluating' in the Science how-to section on page 251.)

Hint 1: Are there systematic errors in the equipment or method steps that consistently affect the results?

Hint 2: Are there random errors, such as variations in measurements or environmental factors, that make the results less consistent?

Hint 3: Could personal errors, such as reading instruments incorrectly or inconsistencies in technique, have affected the investigation?

Aim

To investigate whether a chemical reaction is exothermic or endothermic

Materials

For each group:

- nitrile gloves
- safety glasses
- 5 test tubes
- test tube rack
- 10 mL measuring cylinder
- funnel
- thermometer
- glass stirring rod
- spatula
- 15 mL vinegar
- sodium bicarbonate
- 5 mL of 1 M hydrochloric acid
- 5 mL of 1 M sodium hydroxide
- 5 mL of 1 M copper sulfate solution
- 2 × 3 cm pieces of magnesium ribbon
- 5 mL of 1 M sulfuric acid
- steel wool



HYDROCHLORIC AND SULFURIC ACID ARE HAZARDS. BE CAREFUL. WEAR SAFETY GLASSES AND GLOVES WHILE CONDUCTING THIS INVESTIGATION TO PREVENT ACID FROM BURNING YOUR SKIN OR SPLASHING IN YOUR EYES OR METAL GETTING IN YOUR EYES.

DISPOSE OF WASTES AS INSTRUCTED BY YOUR TEACHER.

Method

- 1 Copy the results table into your notebook, adding a title.
- 2 Place the test tubes into the test tube rack.
- 3 Wearing safety glasses and gloves, use the measuring cylinder to measure the correct amount of reactant 1 for Part A (see Table INV4.6a). Using a funnel, add reactant 1 to a test tube. Rinse the measuring cylinder and the funnel.
- 4 Use a thermometer to measure the temperature of reactant 1. Record the temperature in the results table in the 'Initial temperature' column. Rinse the thermometer.
- 5 Use the measuring cylinder to measure the correct amount of reactant 2 for Part A. Using a funnel, add reactant 2 to the same test tube. Rinse the measuring cylinder and the funnel.
- 6 **a** Gently stir the mixture with a stirring rod. Be careful not to break the base of the test tube. Rinse the stirring rod.
b After a minute, record the temperature of the mixture in the results table in the 'Final temperature' column.
- 7 Record your observations in the results table.
- 8 Repeats steps 3–7 for Parts B, C, D and E.

continues ►



◀ **Figure INV4.6:** In this investigation, you will observe chemical reactions. This is an example of magnesium ribbon reacting to three different acids.

Table INV4.6a: Reactants

Part	Reactant 1	Reactant 2
A	5 mL hydrochloric acid	5 mL 1 M sodium hydroxide
B	5 mL copper sulfate	3 cm piece of magnesium ribbon (cut into small pieces)
C	5 mL vinegar	1 spatula sodium bicarbonate
D	5 mL sulfuric acid	3 cm piece of magnesium ribbon (cut into small pieces)
E	10 mL vinegar	Piece of steel wool

Table INV4.6b: Results

Part	Reactants	Initial temp. (°C)	Final temp. (°C)	Observations
A	Hydrochloric acid + sodium hydroxide			
B	Copper sulfate + magnesium			
C	Vinegar + sodium bicarbonate			
D	Sulfuric acid + magnesium			
E	Vinegar + steel wool (iron)			

Questions

- Identify an assumption made in the method when the final temperature is recorded.
 - Identify a random error in the method and describe its impact on the results.
 - Identify a systematic error that may be present in the method and describe its impact on the results.
 - Describe any personal errors that were made, and suggest how to avoid them if the method were repeated.
- Identify which reactions were exothermic. Explain your choices.
 - Identify which reactions were endothermic. Explain your choices.
- Find a secondary source that classifies the Part A reaction as exothermic or endothermic. Does this match your data?
 - Find a secondary source that classifies the Part C reaction as exothermic or endothermic. Does this match your data?
- Based on the information you found, is your collected data accurate? Give a reason for your response.
- Create a reference to acknowledge the use of the sources of information you found. (Refer to page 268 of the Science how-to for information about referencing.)

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Modelling Earth's structure

Inquiry skill: Planning and conducting

Inquiry skill focus: Identifying scientific equipment

Before starting a first-hand investigation, it is important to identify the equipment that will allow the investigation to be conducted safely and effectively.

Hint 1: What piece of equipment used to measure volume will allow you to collect the most precise measurement?

Hint 2: For help, refer to the 'Using scientific equipment' section on page 287 of the Science how-to.

Aim

To demonstrate how liquids of different densities interact and to use their properties to model the different layers of Earth

Materials

- 5 liquids of different densities (e.g. water, dishwashing detergent, vegetable oil, honey, light corn syrup) (50 mL of each liquid)
- 3 measuring cylinders (one each of 10, 50 and 100 mL)
- 5 × 100 mL beakers
- electronic balance

Method

- 1 Copy the results table into your notebook, adding a title.
- 2 Use the 10 mL measuring cylinder to measure 10 mL of each liquid. Pour each liquid into a separate beaker. Rinse the measuring cylinder between each liquid.
- 3 Use the electronic balance to find the mass of 10 mL of each liquid. Record this information in the results table.
- 4 Work out the density of each liquid and add this information to the results table.
- 5 Use your knowledge of density to work out which liquid represents each of Earth's layers. (*Hint:* The most dense liquid represents Earth's inner core, and the least dense liquid represents the crust.) Check your answer with your teacher. Record this information in the results table.
- 6
 - a Use the 50 mL measuring cylinder to measure 19 mL of the liquid that represents Earth's inner core.
 - b Pour this liquid into the 100 mL measuring cylinder.
 - c Rinse the 50 mL measuring cylinder.
- 7
 - a Measure 35 mL of the liquid that represents the Earth's outer core.
 - b Carefully pour this liquid into the 100 mL measuring cylinder so that it forms a layer on top of the first liquid. (*Hint:* Hold the measuring cylinder at an angle.)
 - c Rinse the 50 mL measuring cylinder.
- 8 Measure 42 mL of the liquid that represents Earth's lower mantle. Carefully add this layer to the 100 mL measuring cylinder.
- 9 Measure 3 mL of the liquid that represents Earth's upper mantle. Carefully add this layer to the 100 mL measuring cylinder.
- 10 Measure 1 mL of the liquid that represents Earth's crust. Carefully add this layer to the 100 mL measuring cylinder.

continues ►

Table INV5.1: Results

Name of liquid	Mass of 10 mL (g)	Density (g/mL)	Earth layer represented	Volume required for scale model (mL)

Questions

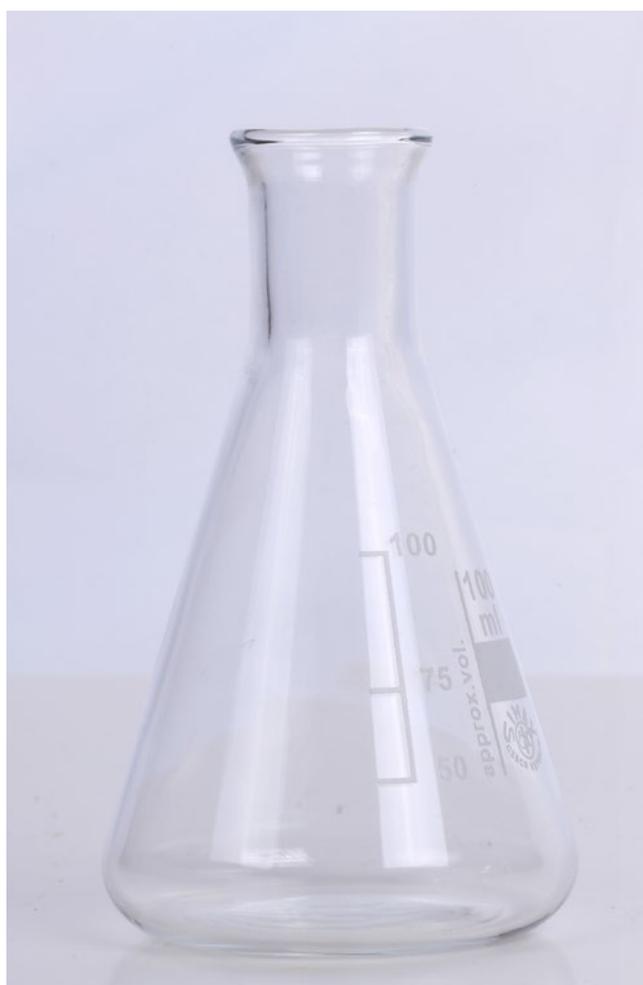
- 1 Draw a diagram of your model of Earth’s structure. Label the diagram.
- 2 Why is it important to know the density of the different substances when making this model?
- 3 a How could making errors in measuring the density of the liquids affect this investigation?
b What could you do to make these errors less likely to happen?
- 4 Explain how the model you have created represents Earth’s layers and the density of the substances in each layer.
- 5 With a partner, brainstorm how this investigation would be different if you did not have access to measuring cylinders with graduations marked on them.

Conclusion

Copy and complete:

‘The results show that: *(respond to the aim)*.’

▼ **Figure INV5.1:** Measuring cylinder with marked graduation



Modelling seafloor spreading

Inquiry skill: Evaluating

Inquiry skill focus: Constructing evidence-based arguments

The results of an investigation can be used as evidence to make claims and construct arguments about scientific concepts and skills. How might the results of this investigation be used to support the theory of plate tectonics?

Hint 1: How does this investigation model seafloor spreading?

Hint 2: Refer to the 'Writing evidence-based essays' section on page 268 of the Science how-to.

Aim

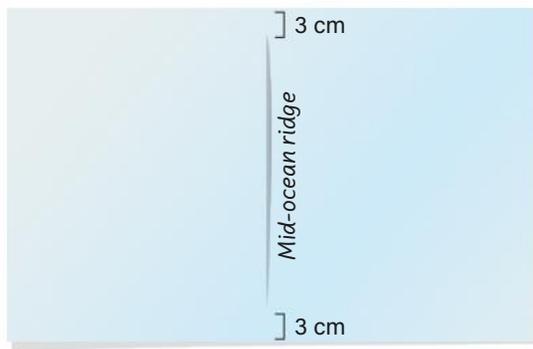
To model the process of seafloor spreading

Materials

- 2 sheets of A4 paper
- ruler
- pencil
- scissors
- sticky tape
- coloured pencils

Method

- 1 Place a piece of A4 paper in landscape orientation. Use the ruler and pencil to draw a straight line down the centre of the paper. Label the line 'Mid-ocean ridge'. Label the line 'Mid-ocean ridge'.
- 2 Carefully use the scissors to cut along the line so there is a slit in the paper. Be careful not to cut to the ends of the paper. Leave about 3 cm either side of the slit.



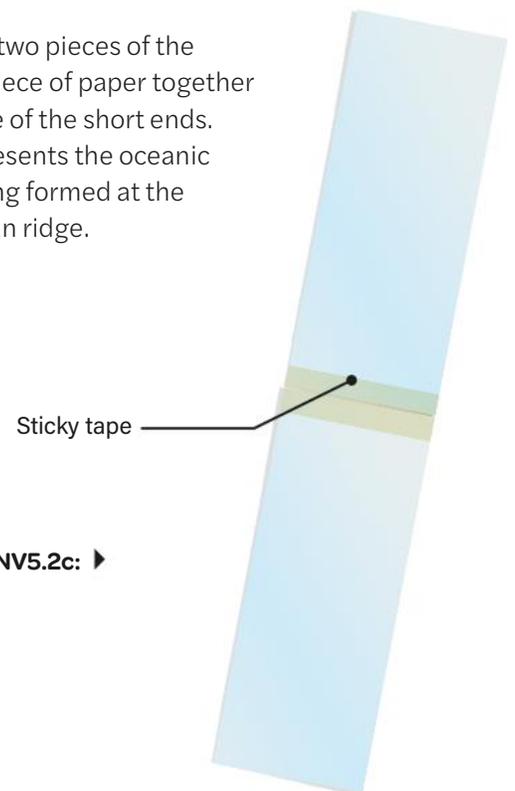
▲ **Figure INV5.2a:** Steps 1 and 2

- 3 Cut the second piece of A4 paper in half lengthwise all the way.



▲ **Figure INV5.2b:** Step 3

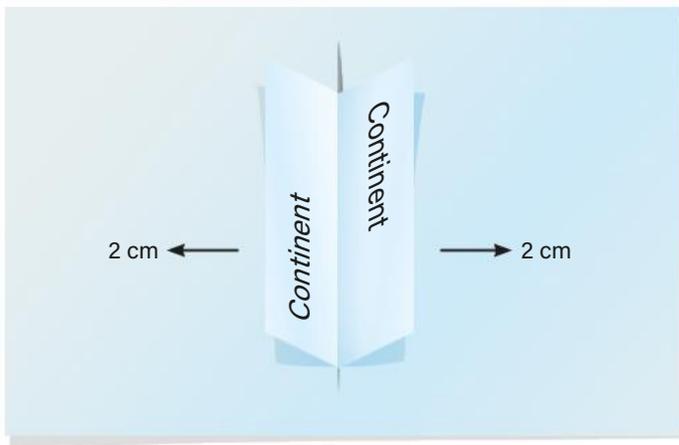
- 4 Tape the two pieces of the second piece of paper together along one of the short ends. This represents the oceanic crust being formed at the mid-ocean ridge.



► **Figure INV5.2c:** Step 4

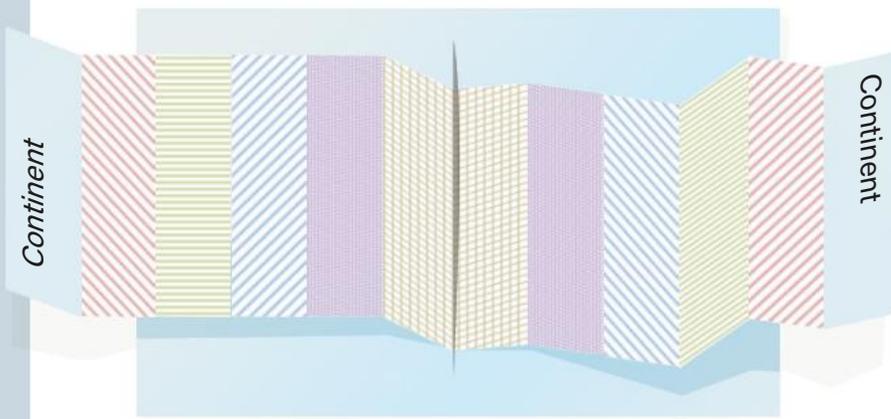
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- 5 Carefully insert the two ends of the second piece of paper into the mid-ocean ridge slit in the first piece of paper (from underneath). Separate the pieces so that one will move towards the left and the other towards the right. Leave about 2 cm exposed.
- 6 Write 'Continent' on both sides of the exposed paper and draw a line where the paper comes out of the mid-ocean ridge.



▲ **Figure INV5.2d:** Steps 5 and 6

- 7 Evenly pull the paper outwards 1–3 cm and colour the white paper with the first colour.
- 8 Repeat step 7, using different colours until all the paper has been pulled through the mid-ocean ridge.



▲ **Figure INV5.2e:** Steps 7 and 8

- 9 Remove the coloured strip of paper for analysis.

Questions

- 1 Identify what the different coloured stripes in your model represent.
- 2 Describe any patterns that you observe in the stripes.
- 3 Your stripes may not all be the same width. What does this represent?
- 4 Critique how well this model demonstrates seafloor spreading. How could it be improved?

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Modelling slab pull

Inquiry skill: Planning and conducting

Inquiry skill focus: Designing scientific investigations

You will work in groups of two or three to produce a plan to create a model that represents the force of slab pull on a tectonic plate. Your student-designed investigation must:

- model slab pull: identify the processes you need to demonstrate
- be safe: identify hazards and describe ways to minimise risk.

Hint: More information is available about planning investigations in the Science how-to on page 236.

Aim

To create a model that represents the force of slab pull on a tectonic plate

Materials

- variety of materials provided by your teacher, such as paper, cardboard, fabric, play dough

Method

- 1 Review the information about how the force of slab pull moves a tectonic plate (see Figure INV5.3A). You could also use the internet to undertake some further research.
- 2 Brainstorm how you could use the materials provided to create a model that represents slab pull moving a tectonic plate.
- 3 Construct your model.
- 4 Share your model with the class.

Questions

- 1 **a** Identify three hazards in this investigation. (*Hint: Which materials could cause injuries?*)
b For each hazard you identified in part a, suggest one way that the risk of the hazard causing harm could be reduced. (How could you prevent injuries from occurring?)
- 2 Identify the materials used to create your model.
- 3 Describe how your model represents the force of slab pull moving the tectonic plate.
- 4 Draw a diagram of your model. Label your diagram.
- 5 Critique your model. Could it be improved?

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

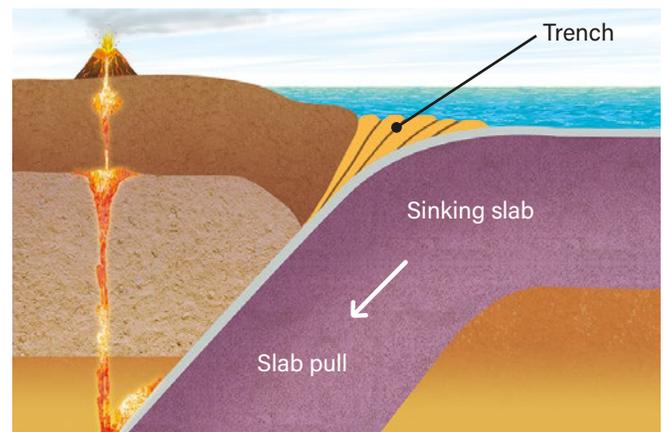


Figure INV5.3A: Slab pull happens when the denser lithosphere sinks slowly underneath the less dense asthenosphere. This is like a rock slowly sinking in water.

Observing convection currents

Inquiry skill: Planning and conducting

Inquiry skill focus: Describing ways to minimise risk

When conducting any first-hand investigation, it is important to use safe practices to minimise the risk of harm. Before you begin, identify any potential hazards and put in place strategies to minimise the chance of accidents or harm occurring in the laboratory.

Hint 1: What materials in this investigation could cause harm if used incorrectly?

Hint 2: What strategies minimise the chance of harm occurring?

Hint 3: More information about assessing risks in first-hand investigations is available in the Science how-to section on page 237.

Aim

To investigate the movement of convection currents

Materials

- safety glasses
- Bunsen burner
- tripod
- 500 mL beaker
- glass tube (or a paper straw)
- matches
- nitrile gloves
- heatproof mat
- wire gauze
- water
- potassium permanganate crystals

Method

- 1 Wearing safety glasses and gloves, set up the Bunsen burner, heatproof mat, tripod and wire gauze (see Figure INV5.3B).
- 2 Fill the beaker with cold water and place it on the wire gauze.
- 3 Carefully drop 1 or 2 crystals into the glass tube while it is sitting in the beaker, so that they drop and stay on the bottom on one side of the beaker, then carefully remove the tube.
- 4 Light the Bunsen burner and turn to the orange flame.
- 5 Observe how the coloured water moves.



AN OPEN FLAME IS A HAZARD. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES. WEAR SAFETY GLASSES AND GLOVES.

DISPOSE OF WASTES AS INSTRUCTED BY YOUR TEACHER.

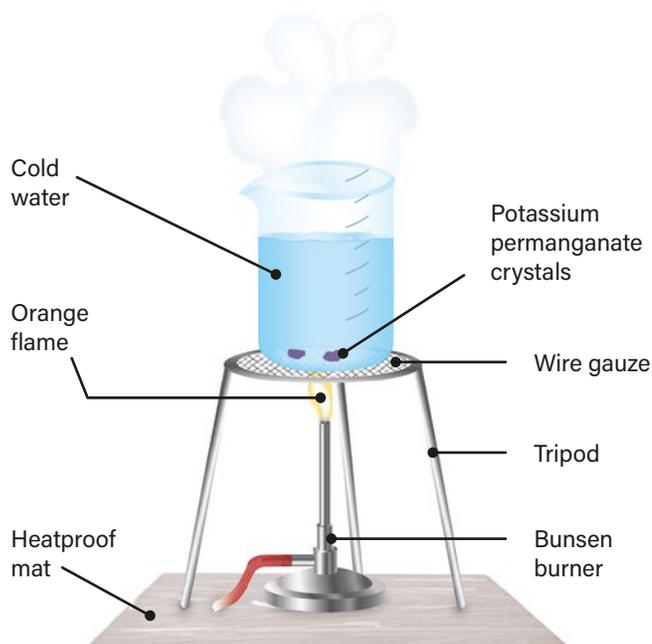


Figure INV5.3B: For this investigation, set up the materials as shown in this diagram.

Questions

- 1 Draw a diagram of the movement of the coloured water. Label the diagram.
- 2 Describe what happened to cause the pattern of movement. Use the terms 'heat' and 'density' in your explanation.
- 3 Relate the movement of the coloured water in the beaker to the movement of rock in Earth's mantle.
- 4 Explain how collecting qualitative first-hand data can assist our understanding of scientific phenomena.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Slinky waves

Inquiry skill: Planning and conducting

Inquiry skill focus: Distinguishing between variables

In an investigation, there should be one independent (changed) variable and one dependent (measured) variable. All other variables should be controlled, or remain consistent throughout all trials of the investigation. This will ensure that the changed variable is responsible for any changes that are observed or measured. What are the variables in this investigation?

Hint 1: What are we changing and measuring in this investigation?

Hint 2: Explain how you controlled three variables in order to ensure that your investigation remained a fair test.

Hint 3: Refer to step 3, 'Planning and conducting investigations', in the Science how-to section on page 238.

Aim

To use slinkies to model different seismic waves

Materials

- video camera (optional)
- 2 slinkies
- 5 cm piece of string
- paperclip

Method

- 1 Copy the results table into your notebook, adding a title.
- 2 Set up the video camera (if you have one) to record the movement of the slinky.
- 3 One person holds one end of a slinky on the ground. A second person holds the other end of the slinky in the air above the first person.
- 4 Tie the string in a bow around one of the coils near the middle of one of the slinkies.
- 5
 - a The first person pulls some coils directly down and releases them.
 - b Observe how the string moves. Record your observations in the results table.
- 6
 - a When the slinky is still again, the first person moves the bottom of the slinky from side to side.
 - b Observe how the string moves. Record your observations in the results table.

- 7 Use a paperclip to create a hook to connect the end of one slinky to the middle of the other slinky. People hold each of the three ends. Hold one slinky vertically and the other one horizontally.
- 8 Tie the string in a bow to the second slinky that is being held horizontally.
- 9
 - a The person holding the bottom of the vertical slinky pulls some coils down and to the side before releasing them.
 - b Observe how the string moves. Record your observations in the results table.

Table INV5.4: Results

Movement	Observations (description of how the string on the slinky moves)
Compression	
Side to side	
Both	

Questions

- 1 Identify what you were modelling at the following steps:
 - a step 5.
 - b step 6.
 - c step 9.
- 2 For this investigation, identify the:
 - a independent variable.
 - b dependent variable.
- 3 Use your answers to Question 2 to write an aim for this investigation.
- 4 Consider how you might improve this investigation to more effectively model seismic waves. Rewrite the method to include your improvements.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'



Figure INV5.4:
In this investigation, you will use two slinkies to model seismic waves.



Viscosity of lava

Inquiry skill: Evaluating

Inquiry skill focus: Constructing evidence-based arguments

The results of an investigation can be used as evidence to make claims and construct arguments about scientific concepts and skills. How might the results of this investigation be used to make recommendations about how people should keep safe around an active lava flow?

Hint: How does viscosity of a substance impact how fast it flows?

Aim

To investigate how the viscosity (thickness) of a substance affects how well it flows over a distance

Materials

- ruler
- 2 spatulas
- thickened cream
- tray
- whipped cream
- 2 stopwatches

Method

- 1 Copy the results table into your notebook, adding a title.
- 2 Measure the length of the tray.
- 3 **a** Use a spatula to place one dollop (about the size of a 20-cent coin) of whipped cream at the end of a tray.
b Use a different spatula to place one dollop (about the size of a 20-cent coin) of thickened cream at the same end of the tray as the whipped cream.
- 4 Start both stopwatches and immediately lift the end of the tray with the cream on it so the tray is at a 45-degree angle.



NEVER EAT ANYTHING IN A SCIENCE LABORATORY.

- 5 Time how long it takes for each dollop of cream to reach the opposite end of the tray. Record this information in the results table.
- 6 Clean and dry the tray and repeat steps 3–5 two more times.
- 7 Calculate the average time each type of cream took to travel the length of the tray. Record this information in the results table.
- 8 Calculate the flow rate of each type of cream. To do this, divide the distance travelled by the average time. Record this information in the results table.

Questions

- 1 **a** Which cream had the fastest flow rate?
b Which cream had the slowest flow rate?
- 2 Describe the relationship between flow rate and the viscosity of the cream.
- 3 Explain how viscosity affected the time it took for the creams to travel down to the end of the tray.
- 4 **a** Which type of cream has a similar viscosity to the lava from a hotspot volcano?
b Which type of cream has a similar viscosity to the lava from a strato volcano?
- 5 Suggest how viscosity of a lava flow might impact how people are evacuated during an eruption.
- 6 Conduct some research to find out how the risks of lava flows are managed in Hawaii. Summarise your findings in a short paragraph, including reference to the viscosity of the lava.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Table INV5.5A: Results

	Time taken to travel the length of the tray (seconds)				Distance (cm)	Flow rate
	Trial 1	Trial 2	Trial 3	Average		
Whipped cream						
Thickened cream						



Wax volcano

Inquiry skill: Evaluating

Inquiry skill focus: Supporting findings with evidence

The results generated and processed in an investigation should always be explained in the discussion of a scientific report using scientific knowledge (see the Science how-to on page 260).

Hint 1: Think about the scientific concepts that are important for the investigation.

Hint 2: Summarise the data and any trends shown in your results.

Hint 3: Explain the data and trends using scientific understanding. For example: 'The results showed that ... This is because ...'

Aim

To model a volcanic eruption using wax

Materials

- safety glasses
- coloured candle wax
- 500 mL beaker
- hotplate
- washed sand
- water
- video camera (optional)



HOT WAX CAN BURN. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES. WEAR SAFETY GLASSES.

Method

- 1 Wearing safety glasses, put the candle wax in the beaker. Heat it on the hotplate until it melts and forms a 1 cm layer in the bottom of the beaker. Allow the wax to set.
- 2 Cover the wax with a 1–2 cm layer of sand.
- 3 Carefully fill the beaker with water.
- 4 Place the beaker on the hotplate and turn on the heat.
- 5 Observe from a safe distance. Record your observations by writing notes in your notebook or by recording a short video.

Questions

- 1 Identify the structures of Earth that are represented by the different layers in the volcanic model you have made with:
 - a wax.
 - b sand.
 - c water.
- 2 Draw a diagram of what your volcano model looks like after you have completed step 3. Label the diagram.
- 3 Review the video of the eruption. Determine an effective way to present the result of the investigation shown in the video.
- 4 Use your scientific understanding of volcanic eruptions to critique this model. How does it reflect real volcanic eruptions? How is it different? How could it be improved?

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Observing minerals

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Organising data

When recording data and observations that are generated during a first-hand investigation, it is important to use a suitable table to keep the information organised. Before you start your investigation, design a table with appropriate columns and rows to record your data and observations.

Hint 1: Read through the method of this investigation to identify what data you need to include in the results table.

Hint 2: Use a ruler to draw your table so it is neat, clear and easy to read.

Hint 3: Label the rows and columns with headings.

Aim

To investigate the properties of some common minerals

Materials

- selection of mineral samples (mineral kit)
- magnifying lens
- streak plate (or an unglazed white ceramic tile)
- nail (or a fingernail, copper coin, glass file)

Method

- 1 Construct a results table in your notebook that will allow you to record the observations you make in this investigation.
- 2 Complete steps 3–6 for each mineral sample. Write your observations in the results table. Use the magnifying lens to examine the samples closely.

- 3 **Lustre:** Determine if each mineral has a metallic or a non-metallic lustre.
- 4 **Colour:** Describe the colour of each mineral.
- 5 **Streak:** Scratch each mineral along the streak plate. Describe the colour of the powder that is left on the plate. *Note:* If a mineral has a measurement of more than 6.5, it will not make a streak. In this case, write 'n/a' ('not applicable') in the results table.
- 6 **Hardness:** Refer to Table 6.1 on page 143 and use the nail and the streak plate to determine the approximate hardness of each mineral.

Questions

- 1 a Which mineral is the softest?
b Which material is the hardest?
- 2 Which property was the easiest to test? Why?
- 3 Explain why we observe both the colour and streak of minerals.
- 4 Is there one property that you could use on its own to tell the difference between the mineral samples? Explain your response.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'



Figure INV6.1A: ▶
A kit of mineral samples



Extracting copper

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Identifying data

When conducting investigations, it is important to identify the type of data that can be collected. It can then be recorded, processed and displayed in an organised way, which will lead to the finding of the investigation. Read the method for this investigation and determine the type of data you will be collecting.

Hint 1: Read carefully through the method of the investigation to identify when you can gather data.

Hint 2: Quantitative data is data that can be counted, measured or represented by numbers.

Hint 3: Qualitative data is data with qualities or characteristics that can be observed and described.

Aim

To investigate how chemical reactions are used to extract copper from a copper ore

Materials

- safety glasses
- nitrile gloves
- 100 mL beaker
- glass stirring rod
- 5 g copper(II) sulfate crystals
- 50 mL distilled water
- zinc metal strip
- camera (optional)

Method

- 1 Wearing safety glasses and gloves, in a beaker, use the stirring rod to carefully dissolve 5 g of copper(II) sulfate crystals in 50 mL of distilled water.
- 2 Add the zinc metal strip to the beaker. Make sure the solution covers the zinc strip.
- 3 Write the heading 'Start of the investigation' in your notebook. Record your observations, including the colour of the solution and of the zinc strip.
- 4 Draw or take a photo of the materials at this stage of the investigation.



COPPER(II) SULFATE IS HAZARDOUS AND SHOULD NOT GO DOWN THE DRAIN. BE CAREFUL. DISPOSE OF WASTES AS INSTRUCTED BY YOUR TEACHER. WEAR SAFETY GLASSES AND GLOVES.

- 5 Leave the solution and the zinc strip in the beaker overnight.
- 6 Write the heading 'End of the investigation' in your notebook. Record your observations, including the colour of the solution and of the zinc strip.
- 7 Draw or take a photo of the materials at this stage of the investigation.

Questions

- 1 Describe the change in the colour of the solution in the beaker.
- 2 Describe the change in the colour of the zinc strip.
- 3 a Which chemical reaction occurred in this investigation? (*Note:* You may need to conduct some research to find out this information.)
b Write a word equation for the chemical reaction that occurred in this investigation.
- 4 Where were the copper atoms located:
a at the start of the investigation?
b at the end of the investigation?
- 5 Describe what this investigation demonstrates about how chemical reactions can be used to extract minerals from ores.
- 6 How can you tell that not all the copper had been extracted from the solution?

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

◀ **Figure INV6.1B:**
Copper(II) sulfate crystals



Modelling the rock cycle

Inquiry skill: Communicating

Inquiry skill focus: Identifying scientific terminology

When conducting investigations, it is important to identify and understand scientific terminology relevant to the topic so that it can be used when recording observations or processing results, and when writing the discussion and conclusion.

Hint 1: Make a glossary of scientific terms related to the rock cycle.

Hint 2: When answering the follow-up questions, try to use as many glossary terms as possible.

Aim

To model the process of the rock cycle using crayons

Materials

- camera
- safety glasses
- butter knife (or plastic knife)
- 2–4 wax crayons of different colours (or plasticine or lollies)
- mortar and pestle
- cutting mat
- rolling pin
- crucible
- Bunsen burner
- heatproof mat
- tripod
- pipeclay triangle
- matches
- brass (crucible) tongs



AN OPEN FLAME AND HOT WAX ARE HAZARDS. BE EXTREMELY CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES. WEAR SAFETY GLASSES.

Method

- 1 Use the camera to take photographs of each step of this process.
- 2 Wearing safety glasses, use the knife to cut the crayons into very small pieces. Keep the colours separate.
- 3 Layer the different colours of crayon in the mortar.
- 4 Use the pestle to gently push down on the crayon layers so they stick together.
- 5 Carefully take the crayon layers out of the mortar and place them on the cutting mat.
- 6 Use the rolling pin to further press down and combine the crayon layers.
- 7 Use the knife to carefully cut out a section of the crayon layers. Place this section into the crucible.
- 8 Set up the Bunsen burner, heatproof mat, tripod and pipeclay triangle.
- 9 Carefully place the crucible without its lid on the pipeclay triangle.
- 10 Light the Bunsen burner and turn it to a blue flame.
- 11 Observe how the wax changes. Once all the wax has melted, turn off the Bunsen burner.
- 12 Remove the crucible with the tongs and allow the melted wax to cool.

Questions

- 1 Identify the rock cycle processes that are modelled by steps 2, 3, 4, 6, 11 and 12.
- 2 Using the processes outlined in Figure 6.11 (page 147), along with the photos you took, create your own rock cycle diagram.
- 3 Evaluate the method of this investigation for its effectiveness in modelling the rock cycle. How could you improve the method?

Conclusion

Copy and complete:

'The results show that: *(respond to the aim).*'

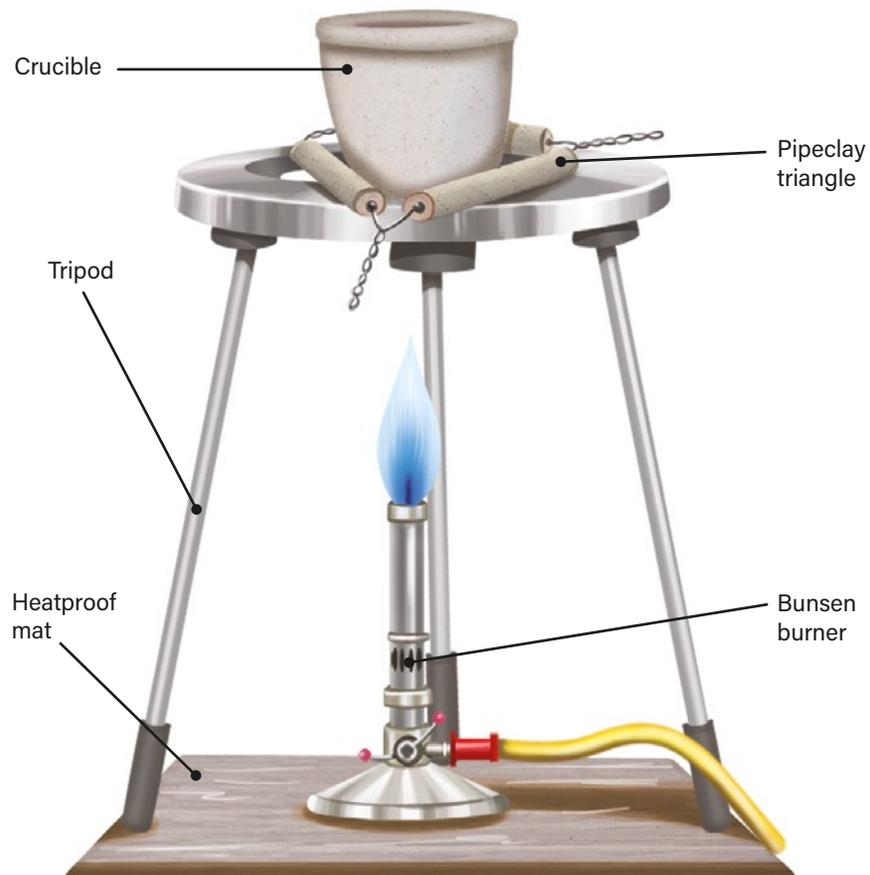


Figure INV6.2: For this investigation, set up the Bunsen burner, heatproof mat, tripod, pipeclay triangle and crucible as shown in this diagram.



Cooling rate and crystal size

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Identifying and discussing trends in data

Scientists analyse the data they collect by identifying and assessing any trends or patterns in their results. These trends can help to identify the relationship between variables, which are discussed later in relation to scientific theory.

Hint: Refer to 'Processing, modelling and analysing' in the Science how-to section on page 240.

Aim

To investigate how cooling rate affects crystal size

Materials

- safety glasses
- 3 test tubes
- ice
- Bunsen burner
- tripod
- 40 mL saturated copper(II) sulfate (or alum) solution
- 10 g copper(II) sulfate crystals
- magnifying lens
- nitrile gloves
- 3 × 250 mL beakers
- cotton wool
- heatproof mat
- gauze mat
- 100 mL beaker
- matches
- thermometer
- glass stirring rod
- beaker tongs

Method

- 1 Wearing safety glasses and gloves, place a test tube into each of the three 250 mL beakers.
 - a Beaker 1: Surround the test tube with ice up to the top of the beaker.
 - b Beaker 2: Surround the test tube with cotton wool up to the top of the beaker.
 - c Beaker 3: Leave the test tube surrounded by air.
- 2 Set up the Bunsen burner, heatproof mat, tripod and gauze mat.
- 3 Add 40 mL of saturated copper(II) sulfate solution to the 100 mL beaker.
- 4 Light the Bunsen burner and turn to a blue flame.



COPPER(II) SULFATE IS HAZARDOUS AND SHOULD NOT GO DOWN THE DRAIN. BE CAREFUL. DISPOSE OF WASTES AS INSTRUCTED BY YOUR TEACHER. AN OPEN FLAME IS A HAZARD. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES. WEAR SAFETY GLASSES AND GLOVES.

- 5 Place the beaker of copper(II) sulfate solution onto the Bunsen burner. Heat the solution to about 40 °C. (Use a thermometer to measure the temperature of the solution.) Turn off the Bunsen burner.
- 6 Add 10 g of copper(II) sulfate crystals to the copper(II) sulfate solution, stirring with the stirring rod until the crystals dissolve. Keep adding the crystals until they no longer dissolve.
- 7 Using the beaker tongs, carefully remove the beaker of the solution from the Bunsen burner. Pour a third of the solution into each test tube.
- 8 Plug the top of each test tube with some cotton wool. Leave the test tubes to cool overnight.
- 9 Use a magnifying lens to observe the size of the crystals in each test tube. Write your observations of the crystals in your notebook.

Questions

- 1 Explain why it was important to plug all three test tubes with cotton wool.
- 2 Identify the speed of cooling (e.g. slow or fast) for the crystals in each beaker.
- 3 a Describe the relationship that you observed between the rate of cooling and the size of the crystals formed.
b Did you expect to see this relationship? Why or why not?
- 4 Which test tube represented the formation of an intrusive igneous rock? Justify your choice.
- 5 Which test tube represented the formation of an extrusive igneous rock? Justify your choice.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Observing igneous rocks

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Organising data

When recording data and observations that are generated during a first-hand investigation, it is important to use a suitable table to keep the information organised. Before you start your investigation, design a table with appropriate columns and rows to record your data and observations.

Hint 1: Read through the method of this investigation to identify what data you need to include in the results table.

Hint 2: Use a ruler to draw your table so it is neat, clear and easy to read.

Hint 3: Label the rows and columns with headings.

Aim

To observe the key characteristics of some igneous rocks

Materials

- selection of igneous rocks (e.g. basalt, granite, pumice, rhyolite, gabbro, obsidian)
- magnifying lens
- ruler

Method

- 1 Construct a results table in your notebook that will allow you to record the observations you make in this investigation.
- 2 Use the magnifying lens to carefully observe each igneous rock sample.
- 3 Estimate the approximate percentage of light minerals and dark minerals in each sample.
- 4 Use the ruler to estimate the average size of the crystals in each sample.
- 5 Record any other observations for each sample.
- 6 Use your observations to estimate if the rock sample cooled quickly or slowly.

Questions

- 1 **a** Identify the extrusive igneous rocks.
b What feature enabled you to identify them?
- 2 **a** Identify the intrusive igneous rocks.
b What feature enabled you to identify them?
- 3 You are walking through the bush and find a rock outcrop. What observations do you need to make to confirm that it is an igneous rock?

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'



◀ **Figure INV6.3B:** Igneous rocks

Modelling contact metamorphism

Inquiry skill focus: Communicating

Inquiry skill focus: Preparing representations to communicate findings

Being able to represent findings in effective and appropriate ways is important for communicating science to others clearly and precisely. After conducting this investigation, you should be able to prepare a representation of your observations to communicate your findings.

Hint: Refer to step 3 of the 'Communicating' section in the Science how-to on page 257.

Aim

To investigate the process of contact metamorphism

Materials

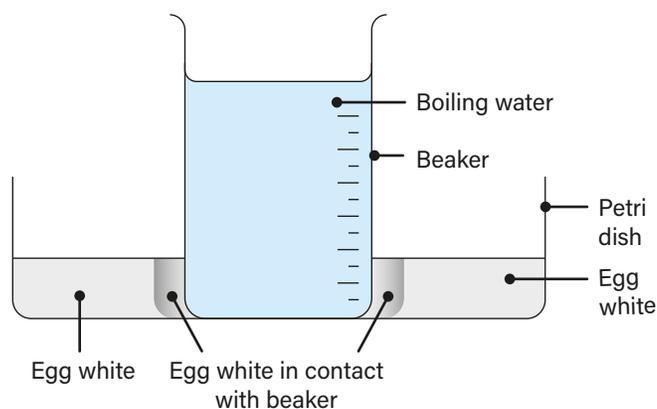
- safety glasses
- raw egg white
- 100 mL beaker
- spatula
- Bunsen burner
- tripod
- matches
- camera (optional)
- vinyl gloves
- 100 mL Petri dish
- tap water
- salt
- heatproof mat
- gauze mat
- beaker tongs

Method

- 1 Wearing safety glasses and vinyl gloves, place the egg white in the Petri dish, making sure there is enough to cover the base of the dish.
- 2 Half fill the beaker with water. Add a spatula of salt to the water.
- 3 Set up the Bunsen burner, heatproof mat, tripod and gauze mat.
- 4 Light the Bunsen burner and set it to the blue flame.
- 5 Place the beaker containing the salty water on the gauze mat and bring the water to the boil.
- 6 When the water is boiling, use beaker tongs to carefully remove the beaker from the gauze mat and place it in the centre of the Petri dish.
- 7 Observe what happens over 10 minutes. Record your observations in your notebook. You may like to take photos to support your observations.



BOILING WATER, STEAM AND AN OPEN FLAME ARE HAZARDS. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES. IF YOU ARE ALLERGIC TO EGG WHITE, TELL YOUR TEACHER BEFORE STARTING THIS INVESTIGATION. NEVER EAT ANYTHING IN A SCIENCE LABORATORY. WEAR SAFETY GLASSES AND GLOVES.



▲ **Figure INV6.4A:** For step 6 of this investigation, set up the materials as shown in this diagram.

Questions

- 1 Draw a diagram that represents your final observations.
- 2 This investigation modelled contact metamorphism.
 - a Explain what the egg white represented.
 - b Explain what the beaker of hot water represented.
- 3
 - a What would happen if you used water that was a different temperature?
 - b Would the water be a controlled, dependent or independent variable?
- 4 Explain how the change to the egg white is similar to the change to rocks that have undergone contact metamorphism.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Observing metamorphic rocks

Inquiry skill: Communicating

Inquiry skill focus: Using digital technologies to communicate findings

Digital technologies allow us to present scientific findings in many different ways. They can be used to construct tables and graphs, as well as to record images and videos. Think about how you could use digital technologies to organise and present your findings for this investigation.

Hint 1: Think about the observations you will be making and the results you will be gathering.

Hint 2: Think about how digital technologies could help you to display your observations and results. For example, you could construct a digital results table on a computer.

Aim

To observe some samples of metamorphic rocks

Materials

- selection of metamorphic rocks (e.g. quartzite, marble, slate, gneiss)
- magnifying lens
- ruler

Method

- 1 Construct a results table in your notebook that will allow you to record the observations you make in this investigation.
- 2 Use a magnifying lens to carefully observe each rock. Observations could include the colour(s) of the crystals in each rock.
- 3 Use a ruler to measure the size of the crystals in each rock. Record these measurements in the results table.
- 4 Does each rock have obvious layers? Record this information in the results table.

Questions

- 1 Use your knowledge of metamorphic rocks to identify each sample as being formed by either contact or regional metamorphism.
- 2 What feature did you use to be able to identify the formation type of each sample?
- 3 You are walking through the bush and find a rock outcrop. What observations do you need to make to confirm that it is a metamorphic rock?

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Figure INV6.4B: Metamorphic rock ▶



Modelling the formation of sandstone

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Analysing scientific models

Using scientific models is useful in helping us to represent the science behind what is happening during an investigation. But we also need to recognise how scientific models can be limited. This is why we analyse scientific models: to evaluate their effectiveness in simulating what is happening in the real world.

Hint 1: Think about what the model is trying to replicate.

Hint 2: What does the model replicate well? What are its weaknesses?

Hint 3: Can you suggest ways to improve the model?

Aim

To investigate, using a model, the formation of sandstone

Materials

- sand: separate samples of different colours
- 0.5 cup dry plaster of Paris
- 2 clear disposable cups
- water
- spatula (or spoon)
- magnifying lens

Method

- 1 Mix the first sample of sand with the dry plaster of Paris.
- 2 Place a layer of sand of one colour into a cup.
- 3 **a** Add a little water to the sand so it is moist but not saturated.
b Use a spatula to combine the sand and water.
- 4 Press the second cup into the first cup to compress the layer of sand.

- 5 Repeat steps 2–4 for sands of different colours.
- 6 Allow your ‘sandstone’ to dry overnight before removing it from the cup.

Questions

- 1 Describe the look and feel of your ‘sandstone’.
- 2 Use a magnifying lens to observe your ‘sandstone’. Construct a diagram of your rock, showing the different sediments.
- 3 Construct a table or a Venn diagram to compare your ‘sandstone’ to a real sample of sandstone.
 - a** What are the similarities?
 - b** What are the differences?
- 4 Identify the steps in the method that represent deposition, compaction and cementation.
- 5 Discuss what this investigation demonstrates about the formation of sandstone.

Conclusion

Copy and complete:

‘The results show that: *(respond to the aim).*’

Figure INV6.5A: Sandstone ►



Observing sedimentary rocks

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Organising data

When recording data and observations that are generated during a first-hand investigation, it is important to use a suitable table to keep the information organised. Before you start your investigation, design a table with appropriate columns and rows to record your data and observations.

Hint 1: Read through the method of this investigation to identify what data you need to include in the results table.

Hint 2: Use a ruler to draw your table so it is neat, clear and easy to read.

Hint 3: Label the rows and columns with headings.

Aim

To observe samples of sedimentary rocks

Materials

- selection of sedimentary rocks (e.g. sandstone, conglomerate, mudstone, shale, limestone)
- magnifying lens
- ruler

Method

- 1 Construct a results table in your notebook that will allow you to record the observations you make in this investigation.
- 2 Use a magnifying lens to carefully observe each rock. Observations could include the colour of the rock, if fossils are present and what types of sediments it is made of.
- 3 Use a ruler to measure the size of the sediments in each rock. Record these measurements in the results table.
- 4 Does each rock have obvious layers? Record this information in the results table.



Figure INV6.5B: ▶
Sedimentary rocks

Questions

- 1 If one of the rock samples did not have obvious layers, what observation did you make that told you the sample is a sedimentary rock?
- 2 **a** Which rock contained the largest sediments?
b Which rock contained the smallest sediments?
- 3 Large sediments are deposited in high-energy environments and small sediments are deposited in low-energy environments. Identify the rock that was deposited in the:
 - a** highest energy environment.
 - b** lowest energy environment.
- 4 You are walking through the bush and find a rock outcrop. What observations do you need to make to confirm that it is a sedimentary rock?

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Making 'fossils'

Inquiry skill: Communicating

Inquiry skill focus: Presenting scientific findings

Scientists can use a variety of representations to simplify and explain ideas. Visual communications make things easier to understand, which helps us to interpret scientific ideas and findings. As you complete this investigation, think about how you could represent the steps in the method using simple diagrams.

Hint: Refer to 'Communicating' in the Science how-to section on page 255.

Aim

To model the formation of a fossil

Materials

- 0.5 cup plaster of Paris
- plastic cup
- water
- popstick
- plasticine
- plastic container (e.g. a take-away food container)
- shell (or other item)
- camera (optional)

Method

- 1 Place the plaster of Paris into a plastic cup.
- 2 Carefully add water to the plaster of Paris. Stir with a popstick until the mixture is the same consistency as toothpaste.
- 3 Press the plasticine into the base of a plastic container and smooth the top.
- 4 Press the shell into the plasticine to make an imprint, then remove it.
- 5 Carefully add a 1–2 cm layer of plaster of Paris on top of the plasticine. Tap the container to remove any air bubbles.
- 6 Leave the plaster to dry overnight.
- 7 Carefully separate the plaster from the plasticine.
- 8 Record your observations in your notebook. You may like to photograph the plaster and the plasticine to support your observations.

Questions

- 1 Construct a series of simple diagrams representing the formation of your 'fossil'.
- 2 Use the terms *deposition*, *compaction* and *cementation* to compare the method you followed in this investigation to the process of fossilisation.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'



▲ **Figure INV6.6:** Clam fossils in limestone

Rolling balls

Inquiry skill: Communicating

Inquiry skill focus: Presenting scientific findings

Scientists can use a variety of representations to simplify and explain ideas. Visual communications make things easier to understand, which helps us to interpret scientific ideas and findings. As you complete this investigation, think about the layout of the results table and why this makes understanding the results easier.

Hint 1: Review your definitions for kinetic and potential energy, and consider how they apply to this investigation.

Hint 2: Refer to 'Communicating' in the Science how-to section on page 255.

Aim

To investigate the relationship between gravitational potential energy and kinetic energy

Materials

- ramp
- milk carton
- electronic balance
- 3 balls or marbles with different masses
- ruler or tape measure

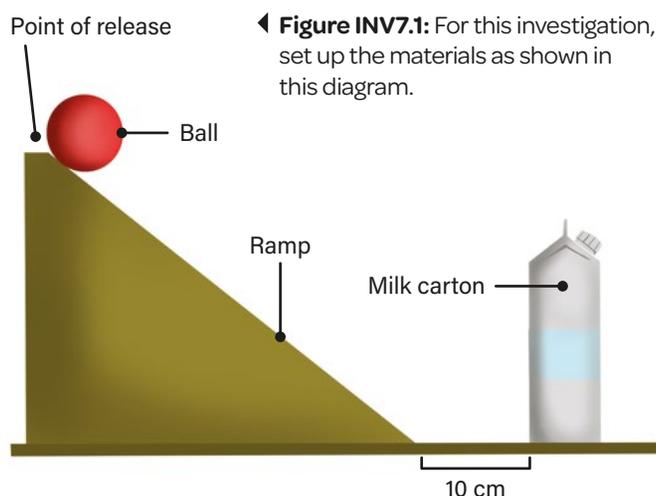
Method

- 1 Copy the results table into your notebook, adding a title and two more rows.
- 2 During the investigation, record in your notebook the observations you make with your senses.
- 3 Set up the materials as shown in Figure INV7.1.
- 4 Use the electronic balance to measure the mass of each ball. Record this data in the results table.

Write the numerical data you collect in steps 5–8 in the results table.

- 5 Roll the first ball down the ramp. Using a ruler, measure the distance the carton moved when the ball hit it.

- 6 Repeat the test four times with the first ball. Make sure the point of release is the same each time.
- 7 Use the results of the five tests to calculate the average distance the carton moved when the first ball hit it.
- 8 Repeat steps 5–7 for the other two balls.



Questions

- 1 Which ball displayed the most kinetic energy at the bottom of the ramp? Suggest a reason for this.
- 2 Which ball had the most gravitational potential energy at the start? Use the observations you made with your senses to support your response.
- 3 Compare the numerical data in the results table to the observations you made with your senses. Are there any trends or patterns? Does any part of the data not make sense?
- 4 Describe how changing the angle of the ramp would affect the gravitational potential energy and kinetic energy.

Conclusion

Copy and complete:

'The results show that: (respond to the aim).'

Table INV7.1: Results

Ball mass (g)	Distance (cm) (test 1)	Distance (cm) (test 2)	Distance (cm) (test 3)	Distance (cm) (test 4)	Distance (cm) (test 5)	Average distance (cm)

Conduction: heat energy transfer in a solid

Inquiry skill: Communicating

Inquiry skill focus: Identifying scientific terminology

When conducting investigations, it is important to identify and understand scientific terminology relevant to the topic, so that you can use it in your records and observations, in the discussion or results, and in the conclusion.

Hint 1: Make a glossary of scientific terms related to conduction.

Hint 2: When answering the follow-up questions, try to use as many of the glossary terms in Section 7.2 as possible.

Aim

To investigate how heat energy is conducted in a solid

Materials

- safety glasses
- heatproof mat
- tray
- Bunsen burner
- matches
- retort stand with bosshead and clamp
- metal bar
- wax beads

Method

- 1 Set up the materials as shown in Figure INV7.2A.
- 2 Wearing safety glasses, light the Bunsen burner and turn it to the blue flame.
- 3 Observe the metal bar and wax beads, and record your observations in your notebook.



AN OPEN FLAME IS A HAZARD. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES.

Questions

- 1 Explain how heat is conducted in a solid, using your observations from this investigation.
- 2 Plan an investigation to demonstrate that heat energy is transferred through different metals at different rates.
- 3 Create a glossary for this investigation that includes five key words.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

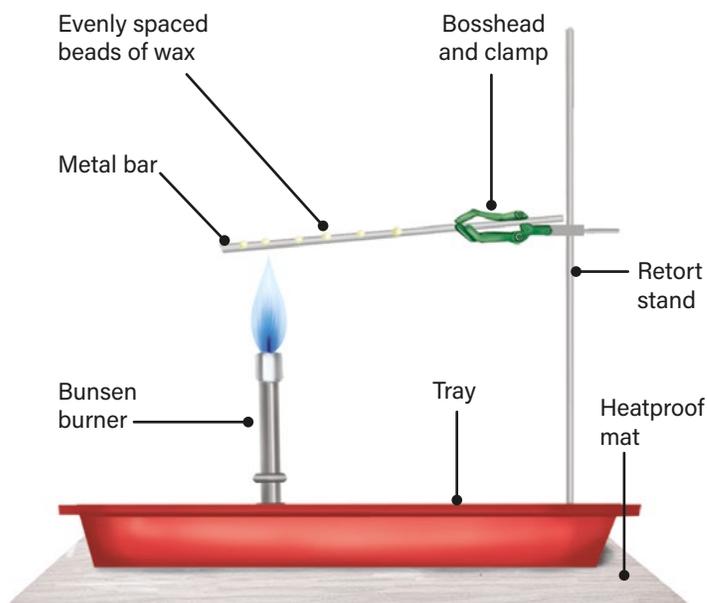


Figure INV7.2A: For this investigation, set up the materials as shown in this diagram.

Convection: heat energy transfer in a liquid

Inquiry skill: Communicating

Inquiry skill focus: Preparing representations to communicate findings

After conducting this investigation, you will be required to prepare a representation (diagram) to communicate your findings. Being able to represent findings in different formats is important for communicating science to others in clear and precise ways.

Hint: Review the meaning of convection in Section 7.2 to help with your explanation.

Aim

To investigate how heat energy is conducted in a liquid

Materials

- cold water
- 600 mL beaker
- red food colouring
- 50 mL conical flask
- hot tap water (40–50 °C)
- long-handled flask tongs (or crucible tongs with bow)

Method

- 1 Add cold water to the beaker until it is 3 cm from the top.
- 2 Place a few drops of red food colouring into the conical flask, then fill it almost to the top with hot water.
- 3 Using long-handled tongs, carefully lower the small conical flask into the beaker. Take care not to spill the hot water or to disturb the flask too much.
- 4 Record your observations.

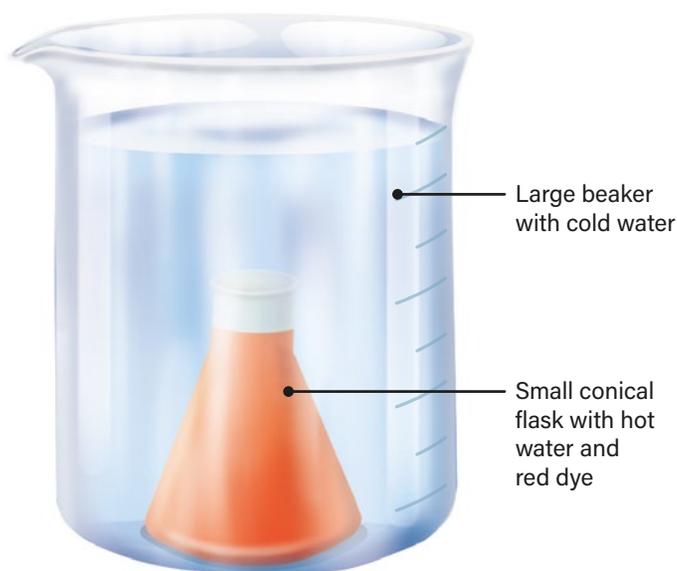
Questions

- 1 Construct a diagram that shows the movement of the hot water in the cold water.
- 2 Explain how convection works in a liquid, using your observations from this investigation.
- 3 Identify the independent, dependent and controlled variables of this investigation.
- 4 Propose another way that you could prepare a representation to communicate your findings.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim).*'



▲ **Figure INV7.2B:** For this investigation, set up the materials as shown in this diagram.



Energy transformations

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Identifying and discussing trends in data

After making observations and collating these in your data table, you will look for patterns and similarities in relation to how energy is transferred or transformed in each example and represent energy changes as flowcharts.

Hint 1: Complete Question 1 before starting this investigation.

Hint 2: Revise the difference between energy transfer and energy transformation to help you identify the energy changes in each example.

Aim

To observe and record how energy is transformed in a variety of familiar systems

Materials

- safety glasses
- sand or gravel (to fill the beaker)
- torch
- elastic band
- damp rag
- hair dryer
- 250 mL beaker
- sparkler
- matches
- tennis ball
- peg
- retort stand

Method

- 1 Copy the results table into your notebook, adding a title. After you complete each of steps 2–6, fill in the row of the results table for that step.



MATCHES, SPARKLERS AND HAIR DRYERS ARE ALL HAZARDOUS. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES.

- 2 Fill the beaker with sand. Stand a sparkler in the sand. Wearing safety glasses, use a match to light the sparkler.
- 3 Turn the torch on and off.
- 4 Roll a tennis ball off the edge of a bench.
- 5 Hold an elastic band between your finger and thumb. Stretch the elastic band back with your other hand and let it go.
- 6 Peg a damp rag to a retort stand. Turn on the hair dryer and blow warm air over the rag.

Questions

- 1 **a** Work with a partner to identify three hazards in this investigation.
 - b** Suggest one way that the risk of each hazard causing harm could be reduced.
 - c** What other aspects of investigations are important to consider from a safety point of view?
- 2 What type of potential energy did each system begin with?
- 3 Explain whether each system still had potential energy once the experiment was complete.
- 4 Draw an energy flowchart to represent the energy transformations that took place in each system.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Table INV7.3: Results

Step	System	Type of energy that initiated the change	Observations (dot points)	Energy transformations observed
2	A sparkler burns			
3	A torch is turned on			
4	A tennis ball falls			
5	An elastic band is stretched and released			
6	A hair dryer blows warm air over a damp rag			

Comparing energy in appliances

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Processing data

Data can be processed in different ways. One way is by collecting raw measurements and then using mathematical relationships to calculate a new value. This investigation requires you to collect data about electrical appliance efficiency from a secondary source and to process it in a table. You will then use criteria to compare appliances and analyse efficiency.

Aim

To investigate energy efficiency data for appliances in order to compare the energy transformed over time

Materials

- access to the Australian Government energy rating website

Method

- 1 Go to the Australian Government energy rating website or search for 'energy rating website'.
- 2 Click on the energy rating calculator.
- 3 Select an appliance type you would like to investigate.
- 4 Use the 'filters' on the left to select the features of an appliance. For example, a television will allow you to select the screen type and size, and a washing machine will allow you to select the capacity (how large it is).

- 5 Copy the results table on the next page into your notebook and complete the information for four appliances in your category. Each appliance you collect data about must have a different star rating. (Do not record data for appliances with the same rating.) You can use the comparison tool to get this data.
- 6 After recording the data available from the website, calculate the remaining table rows about energy use over a month, a week and a day.

Questions

- 1 Explain the relationship between the amount of energy used in the appliances and the star rating.
- 2 Calculate the difference in energy used by your most efficient and least efficient appliance over one year.
- 3 Calculate the difference in cost between your most and least efficient appliance over:
 - a one year.
 - b one month.
- 4 Reflect on the amount of energy used by a single appliance, and on how many appliances may be used in your house. Estimate the possible electricity bill for your house over one month.
- 5 Based on your data and evidence collected, evaluate which appliance is the best choice and why. In your answer, explain the criteria you used to make this choice.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

continues ►

Table INV7.5: Results

	Appliance 1	Appliance 2	Appliance 3	Appliance 4
Appliance features				
Star rating				
1-year energy use				
Tariff				
1-year running cost				
10-year running cost				
Calculate the following for each appliance:				
1-month running cost				
1-week running cost				
1-day running cost				

Figure INV7.5: Appliances have different energy star ratings based on how efficient they are.



Thermal energy and colour

Inquiry skill: Communicating

Inquiry skill focus: Preparing representations to communicate findings

Being able to represent findings in effective and appropriate ways is important for communicating science to others clearly and precisely. After conducting this investigation, you should be able to prepare a representation in the form of an evidence-based scientific argument to communicate your findings.

Hint 1: Refer to step 5 of 'Communicating' in the Science how-to section on page 258.

Hint 2: Look for and identify the energy transfers and energy transformations involved as you complete the investigation.

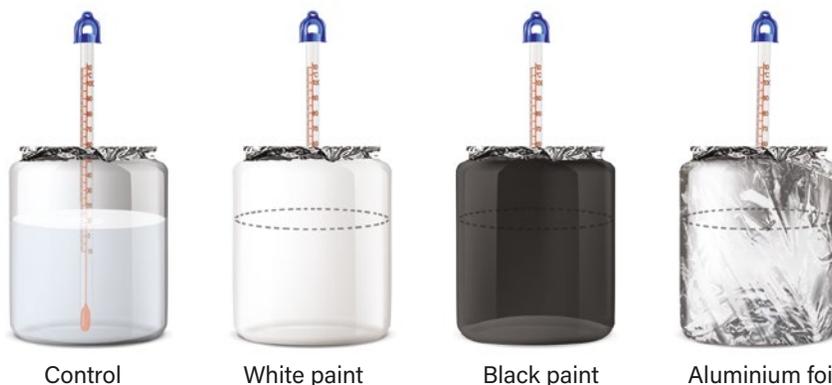
Aim

To investigate how the colour of objects affects their thermal energy, measured as temperature

Materials

- 4 small glass jars of the same size and shape (or use beakers or flasks)
- black paint, white paint and aluminium foil (or cover the glass jars in white and black paper, but paint is more effective)
- paintbrush
- measuring cylinder
- tap water
- 3 thermometers
- heat source, either sunlight or a heat lamp

Figure INV7.6: The set-up ► for measuring the temperature of different-coloured jars



Method

- 1 Keep one jar as clear glass. This is your control.
- 2 Paint or cover one jar to make it white and another black. Cover the third one with aluminium foil. If covering your jars, ensure the covering is as tight as possible against the glass.
- 3 Using the measuring cylinder, fill each jar with an equal amount of water of the same temperature. The amount of water will depend on how large the jars are. Each jar should be filled close to the top with water.
- 4 Place a thermometer in each jar and cover the top with aluminium foil. The thermometer should remain inside the jar.
- 5 Copy the results table from the next page into your notebook, adding a heading.
- 6 Take the initial water temperature reading. Each jar should be the same temperature at this stage. If not, refill your jars with water and try again.
- 7 Place all jars in sunlight, or if using a heat lamp, ensure that all jars are the same distance from it.
- 8 Record the temperature every 4 minutes for at least 30 minutes, or longer if the heat is rising only slowly.
- 9 After 20 minutes of the heating period, touch the outside of each jar on the side facing the heat source and record your observations.

continues ►

Questions

- 1 Identify the key forms of energy involved in this investigation.
- 2 Identify and describe the energy transfers and energy transformations occurring in the investigation.
- 3 Construct a line graph of temperature (y-axis) against time (x-axis), showing each jar.
- 4 Identify the colour that was best at absorbing heat. Justify your answer with evidence.
- 5 Identify the colour that was worst at absorbing heat. Justify your answer with evidence.
- 6 Using what you have learnt, explain why it is important to consider the colour selected to build the roof of a house.

7 In relation to energy transfer:

- a List the key information you would communicate to an architect who is designing a new house.
- b Construct a scientific argument that includes evidence from your investigation to communicate this information clearly to the architect.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Table INV7.6: Results

Colour of jar	Water temperature (°C)				
	Time (minutes)				
	0	4	8	12	16
Control					
White					
Black					
Reflective (foil-covered)					

Insulation and heat transfer

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Identifying and discussing trends in data

Scientists analyse the data they collect by identifying and assessing any trends or patterns that can be seen in visual representations of information, such as graphs. These trends can help to identify the relationship between variables and can then be discussed in relation to scientific theory.

Hint 1: Refer to 'Processing, modelling and analysing' in the Science how-to section on page 240.

Hint 2: Think about how energy is transformed, transferred, reflected, conducted and radiated in each of the examples of the flasks that you test.

Aim

To investigate insulating materials and the transfer of thermal energy, measured as temperature, to see if some materials are better insulators than others

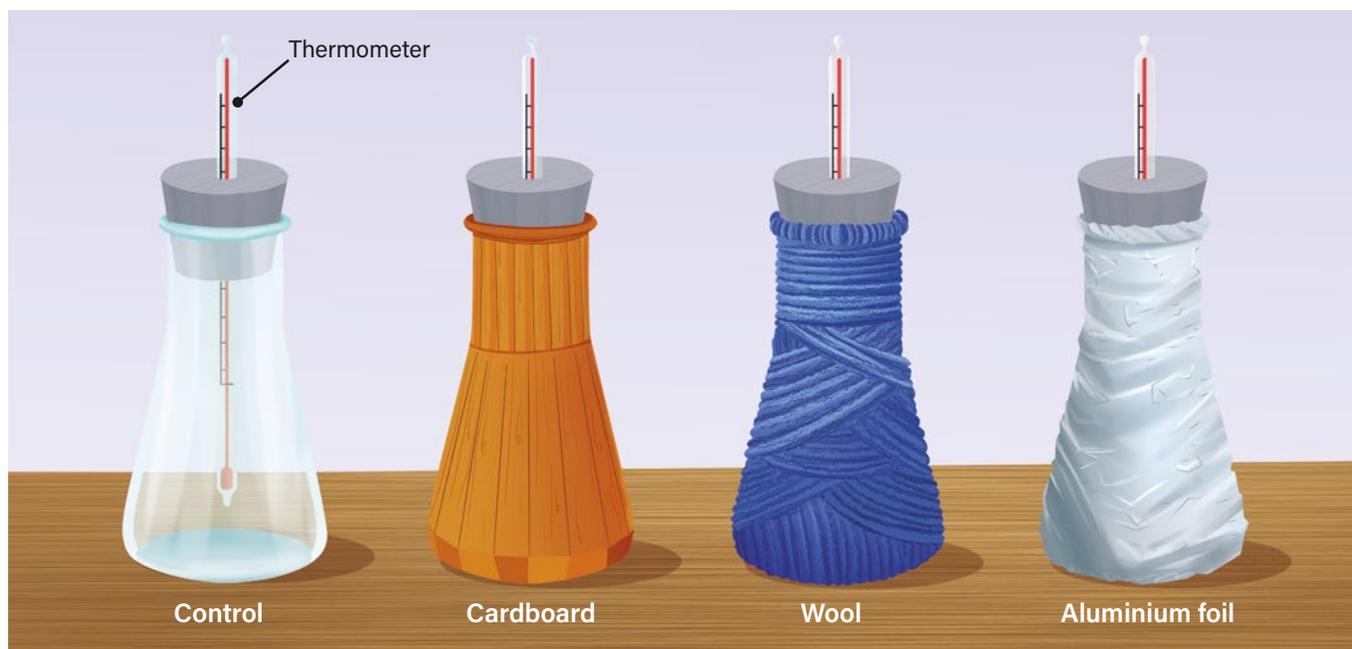


USING HOT WATER CAN BE DANGEROUS, AND BOILING OR HOT WATER IS A HAZARD. WEAR SAFETY GLASSES DURING THIS INVESTIGATION. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND RUN COLD WATER OVER THE AFFECTED AREA FOR 20 MINUTES.

Materials

For entire class:

- safety glasses
- selection of 3 insulating materials (e.g. cardboard, wool, aluminium foil)
- 4 × 250 mL conical flasks (one for each material)
- scissors
- tape
- kettle (or hot water from tap)
- 4 rubber stoppers with hole
- 4 thermometers



▲ **Figure INV7.7:** Set up your conical flasks, with one as a control and the others with insulation.

continues ►

Method

- 1 Copy the results table into your notebook, adding a title.
- 2 Leave one conical flask free of insulating material. This will be your control.
- 3 Wrap an insulating material around each of the other three conical flasks and secure it with tape.
- 4 Add equal volumes of hot water to the flasks.
- 5 Insert a rubber stopper in the neck of each flask to seal it.
- 6 Place a thermometer in each flask and secure through the hole in the rubber stopper. Ensure you add a rubber stopper to the control.
- 7 Allow enough time for the temperature reading on the thermometer to stabilise. Record this initial temperature in your results table.
- 8 Record the water temperature for each flask every 5 minutes for half an hour.

Questions

- 1 Identify the key forms of energy involved in this investigation.
- 2 Describe the energy transfers occurring in the investigation.

- 3 Construct a line graph of temperature (y -axis) against time (x -axis) showing each insulator.
- 4 Identify the material that was the best insulator. Justify your answer with evidence.
- 5 Identify the material that was the worst insulator. Justify your answer with evidence.
- 6 Different insulators have different features or properties.
 - a Describe the properties of aluminium foil and explain how these properties make aluminium foil an insulator of heat.
 - b Wool is also a good insulator. Explain the features that make wool effective at reducing heat loss.
- 7 Propose reasons why a shiny silver 'space blanket' is used by emergency workers to cover people at the scene of an accident.
- 8 Apply what you have learnt to propose a design for a flask that aims to keep tea hot for as long as possible.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Table INV7.7: Results

Insulating material	Water temperature (°C)						
	Time (minutes)						
	0	5	10	15	20	25	30
Control							
Material A							
Material B							
Material C							

Household energy audit

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Identifying and discussing trends in data

Scientists analyse the data they collect by identifying and assessing any trends or patterns that can be seen in visual representations of information, such as tables. These trends can help to identify the relationship between variables and are discussed later in relation to scientific theory.

Hint 1: Refer to 'Processing, modelling and analysing' in the Science how-to section on page 240.

Hint 2: As you complete this audit, consider the scientific concepts you have learnt about (including energy forms, transfers, transformations, efficiency and waste) and how they apply in your home.

Aim

To undertake an energy audit of your household and identify opportunities for improving energy efficiency

Materials

- energy audit checklist (see Table INV7.8 – your teacher will make an editable version available to you)
- a home energy bill for gas or electricity, or both, from your household
- a compass (or use your mobile phone)

Method

- 1 Undertake your energy audit by completing the audit checklist in Table INV7.8.
- 2 As you work through the checklist, you may need to ask your parents for help with answering some questions. If you cannot answer all the items in the audit, just complete as many as possible. For example, if no one knows whether there is insulation in your ceiling and you are unable to take a look, it is okay to skip that item and leave the column blank.
- 3 For each item, record data or information as asked.

- 4 In each section of the checklist, there are some blank lines. Use these to record any other things you see in your household that may increase or reduce your energy efficiency. Give these a rating.
- 5 After you have collated the data for each item, based on what you have found out, assess the energy efficiency and give it a rating as 'low efficiency', 'medium efficiency' or 'high efficiency'. This rating will be your opinion. For example:
 - a If you are asked to assess the colour of your roof, black would be low efficiency, white or silver roofing would be high efficiency, and orange tiles would probably be rated as medium efficiency.
 - b If you assess that people in your household turn off the lights only some of the time, this behaviour would probably be rated as medium efficiency. But if people *never* turn off the lights when leaving the room, it would be low efficiency.
 - c If only some light bulbs are upgraded to energy-efficient LEDs, but not all of them, then your rating is probably 'medium'.
- 6 Once you have completed the audit, total up the number of low, medium and high ratings in the boxes in the list.
- 7 Using your ratings, assess the overall rating for your household, based on the column that has the highest total.

Questions

- 1 Explain the difference between energy efficiency, waste and consumption.
- 2
 - a Based on your assessment and the total score, evaluate the overall energy efficiency rating for your household.
 - b Are there any main sections of the audit that were rated as high in energy efficiency? Justify your answer.
 - c Are there sections of the audit that were rated as low? Justify your answer.

continues ►

- 3 a** Propose three changes you could make to immediately improve the energy efficiency rating of your household.
- b** Do you think your household would take these steps? Explain your response.
- c** Describe ways that you could make it more likely that these changes would be successful.

- 4** Assess whether you think that behaviour or structural design features will be the best way to improve energy efficiency in a household.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Table INV7.8: Energy audit checklist

Energy audit item		Response (yes/no)	Efficiency energy rating (tick)		
			Low	Medium	High
Heating and cooling	In summer, the temperature on the cooler thermostat is set no lower than 24°C.				
	In summer, the temperature on the cooler thermostat is set at between 20°C and 22°C.				
	At night, we turn the heater/cooler off or turn it down low.				
	If you have a fireplace, do you have a way to block the chimney when not in use?				
	Are heaters, or heating and cooling vents, clean of blockages like curtains or furniture?				
	Are heating/cooling systems and ducts cleaned at least once a year?				
	Do you always shut the doors and windows when the heater or cooler is running?				
Subtotal					
Building	Is there insulation inside the ceiling or roof space?				
	Is there insulation inside the walls?				
	Is there insulation under the floor?				
	Are the eaves (the edge of the roof) wider and poke out past the walls to create shade on the walls and windows in the heat of the day?				
	Is the colour of the outside walls light?				
	Is the colour of the roof light or reflective?				
	Are there a lot of concrete or paved areas and few gardens?				
	Are there other building design features that help with energy efficiency? Describe.				
Subtotal					

Energy audit item		Response (yes/no)	Efficiency energy rating (tick)		
			Low	Medium	High
Windows and doors	Are there blinds, trees or other ways to shade the windows on the west side of the house from the direct afternoon sun?				
	Are there windows on the north side of the house to let sun in during winter?				
	Are there curtains or blinds on the inside of windows?				
	Are the windows double glazed?				
	Do windows have gaps around the edge where they close that allow air to enter or exit?				
	Are the gaps around windows sealed with weather strips such as foam or material that stops drafts, or are they designed to stop drafts?				
	Are the windows tinted?				
	Are the gaps around doors sealed with foam, weather strips at the bottom, or other material that stops drafts?				
Subtotal					
Water use and water heating	Are hot water pipes insulated?				
	Is the hot water temperature set at 50–60 °C?				
	Are all showers fitted with low-flow shower heads to save water?				
	Do members of the household turn off taps while brushing teeth, shaving or performing other activities?				
	Are showers normally shorter than 5 minutes?				
	Is the washing machine used on a cold wash most of the time?				
	Do you have a heat pump/solar hot water or gas/electric hot water?				
Subtotal					

continues ►

Energy audit item		Response (yes/no)	Efficiency energy rating (tick)		
			Low	Medium	High
Appliances	Do you usually run the dishwasher when completely full?				
	Do you usually run the washing machine when completely full?				
	Do you normally hang clothes on the clothes line, and only use the clothes dryer when it is too cold to hang out washing?				
	Is there at least 2 cm of space around each side of the refrigerator to ensure air circulation?				
	Do members of the household turn off lights when they leave a room?				
	Are all light bulbs energy efficient?				
	Is there an electric cooktop rather than gas?				
	Find the rating of the following appliances. You may need to find the model number on the appliance and search the internet to find the rating:				
	▪ Television (you may have more than one)				
	▪ Dishwasher				
	▪ Washing machine				
	▪ Clothes dryer				
	▪ Oven				
	▪ Microwave				
	▪ Air conditioner/heater				
Subtotal					
Energy bills	When comparing our household gas bill, we use less, more or the same energy as similar-sized households.				
	When comparing our household electricity bill, we use less, more or the same energy as similar-sized households.				
Subtotal					
OVERALL TOTAL (Add up all subtotals)					

Magnetic shielding

Inquiry skill: Questioning and predicting

Inquiry skill focus: Making predictions

A key component of first-hand investigations is making a prediction of the outcome of the investigation. You may not know much about the concepts under investigation yet, so sometimes it is okay to make a prediction based on what you have experienced or observed. To make your predictions, answer Questions 1 and 2 before you start this investigation.

Hint 1: Think about how fields work and what materials may block a field.

Hint 2: More information about making predictions is available in the Science how-to section on page 232.

Aim

To test which materials can block a magnetic field

Materials

- retort stand, bosshead and clamp
- bar magnet
- 50 g mass
- paperclip
- cotton thread
- ruler
- sheets of different material such as cardboard, aluminium, plastic, steel, tin, wood, a ceramic tile, copper

Method

- 1 Copy the results table into your notebook, adding a title and as many rows as needed.
- 2 Set up the equipment as shown in Figure INV8.1.
- 3 Find the maximum distance that can be left between the paperclip and the magnet before the paperclip drops. Record the maximum distance.
- 4 Insert each different material between the magnet and the paperclip. Record what happens in the results table.

Questions

- 1 In terms of the strength of the magnetic field, explain why the paperclip fell when the distance between the paperclip and the bar magnet increased.
- 2 Which materials blocked the magnetic field and which materials did not?
- 3 Which other materials do you think block magnetic fields?
- 4 In scrapyards, electromagnets are used to sort the scrap material. Suggest which materials are removed from the scrap pile by the magnet.

Table INV8.1: Results

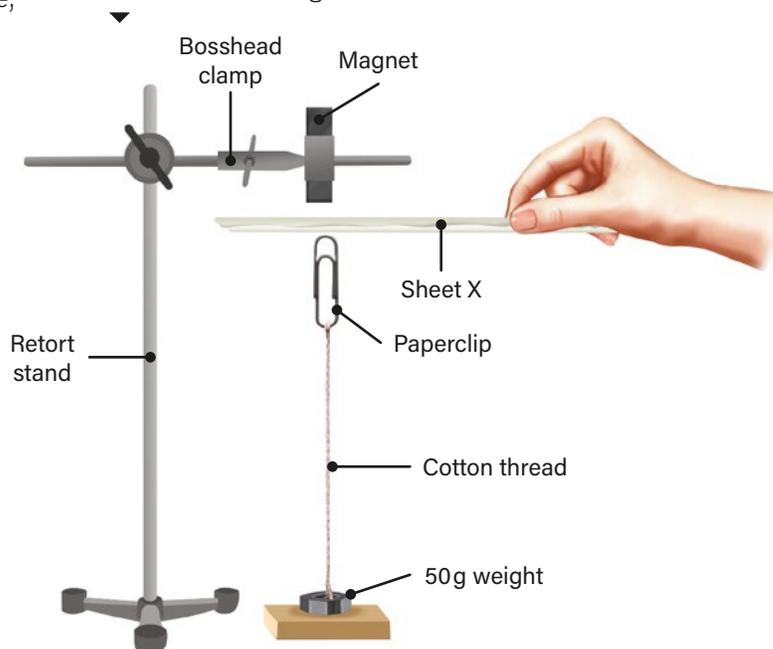
Material	Paperclip stayed or dropped

Conclusion

Copy and complete:

'The results show that: *(respond to the aim).*'

Figure INV8.1: For this investigation, set up the materials as shown in this diagram.



Charging balloons

Inquiry skill: Evaluating

Inquiry skill focus: Constructing evidence-based arguments

The results of an investigation can be used as evidence to make claims and construct arguments about scientific concepts and skills. How might the results of this investigation be used to make a claim about electrostatic forces?

Hint 1: Revise the three types of charges and think about whether they will attract or repel or do neither.

Hint 2: Refer to the 'Writing evidence-based essays' on page 268 in the Science how-to section.

Aim

To investigate the behaviour of charged objects

Materials

- tissues
- plastic rod
- piece of furry fabric
- 2 balloons
- 2 × 30 cm lengths of string

Method

- 1 Complete Question 1 before you do this activity.
- 2 Tear the tissues into small squares of 1 cm × 1 cm.
- 3 Rub the plastic rod with the furry fabric vigorously for 1 minute.
- 4 Place the tip of the plastic rod close to, but not touching, the tissue squares. Record your observations.
- 5 Inflate the balloons and tie a 30 cm length of string to each one.
- 6 Rub the balloons against your hair for 1 minute. Record your observations.
- 7 Repeat step 6 with a partner, so that each of you now holds a charged balloon. Hold each balloon by the string and move them close together (but not touching). Record your observations.

Questions

- 1 Read the method. Predict what will happen to the tissue squares and balloons. This is your hypothesis. Write your hypothesis in your notebook using the format below.
If ..., then ..., because ...
- 2 What did you observe happening to the tissue squares?
- 3 What did you observe happening to the balloons?
- 4 Explain the behaviour of the tissues and balloons in terms of electrostatic charge. Did this match your hypothesis?
- 5 Construct an argument to support the theory of electrostatic charges, using the findings and observations as evidence for your claims.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'



▲ **Figure INV8.2:** Step 6 of this investigation: rub the balloons against your hair.

Modelling a simple circuit

Inquiry skill: Evaluating

Inquiry skill focus: Supporting findings with evidence

The observations generated and processed in an investigation should be explained in the discussion of a scientific report using scientific knowledge. (See the Science how-to section on page 260.)

Hint 1: Think about the scientific concepts that are important for the investigation.

Hint 2: Summarise how the observations link to the concepts of voltage, current and resistance.

Hint 3: Explain your findings using scientific understanding. For example: 'The results showed that ... This is because ...'

Aim

To model a simple circuit and the concepts of current, voltage and resistance

Materials

For entire class:

- 2 pairs of thick fabric gloves
- a piece of rope at least 4 m long, tied in a loop

Method

- 1 As a class, stand in a circle, holding the rope very loosely.
- 2 One student acts as the battery and adds voltage to the circuit by pulling one end of the rope. Observe what happens to the rope. (It should move in a circle.)
- 3 The student increases the energy with which they pull the rope, just like a battery adding more voltage. Observe what happens to the speed of movement of the rope.
- 4 One or two students act as resistors. They put on gloves and then hold the rope a little more tightly than the others. Observe what happens to the speed of movement of the rope as resistance is added.



BE CAREFUL WHEN PULLING THE ROPE, AND ONLY PULL GENTLY WHEN EVERYONE IS READY. PULLING A ROPE QUICKLY THROUGH SOMEONE'S HANDS CAN CAUSE ROPE BURN.

Questions

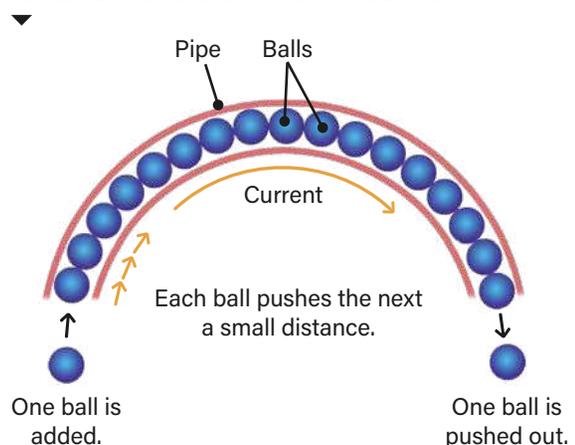
- 1 In what ways are models (like this one) helpful in demonstrating scientific concepts?
- 2 Explain what the moving rope represents, in relation to current and voltage.
- 3 Explain, in your own words, the role of the resistors in an electric circuit.
- 4 Predict what happens to the energy in the rope as it passes through the gloves (resistors) in this model.
- 5 Based on your observations of the model, make an inference about what would happen to the voltage in a real circuit when the resistance is changed.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Figure INV8.5A: In what ways is the rope model similar to or different from the model shown?



Conductors and insulators

Inquiry skill: Evaluating

Inquiry skill focus: Describing types of errors

Investigations are never perfect. There are often errors in the method or equipment that impact the results and must be identified. Acknowledging and describing various types of errors helps to evaluate the reliability of your results and allows improvements to be made in future investigations. (See step 2 of 'Evaluating' on page 251 in the Science how-to section.)

Hint 1: Are there systematic errors in the equipment or method steps that consistently affect the results?

Hint 2: Are there random errors, such as variations in measurements or environmental factors, that make the results less consistent?

Hint 3: Could personal error, such as reading instruments incorrectly or inconsistencies in technique, have affected the investigation?

Aim

To investigate which materials are electrical conductors, and which are insulators, in an electrical circuit

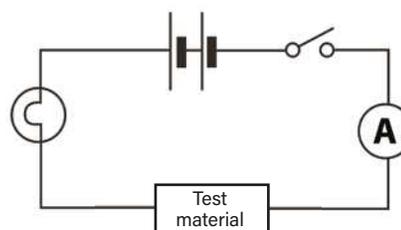
Materials

- variable power supply
- ammeter
- switch
- 12 V, 10 W light bulb
- conducting wires with alligator clips
- conducting wires with banana plugs or alligator clips – suitable for a power pack
- selection of materials (e.g. fabric, different plastics, iron nail, strip of tin, popstick, strip of copper, strip of aluminium, chalk, graphite from a pencil, glass)

Method

- 1 Copy the results table into your notebook, adding a title and rows as needed.
- 2 Copy the circuit diagram and label all the symbols used.
- 3 Set up the circuit as shown in the diagram.
- 4 Set the power supply to 6 V on the direct current setting.

- 5 Attach both contacts to one of the materials.
- 6 Switch on the power to the circuit and record your observations of the light bulb. Also record the ammeter reading.
- 7 Repeat steps 5 and 6 for each material.



◀ **Figure INV8.5B:** Testing circuit with a light and an ammeter

Questions

- 1 Outline how your observations helped you to identify whether a substance was an insulator or a conductor.
- 2 Were some conductors better than others? Explain how you can tell.
- 3 **a** Based on your results, did the conductors have anything in common?
b Were there any exceptions?
- 4 Use the definition of current to help you explain what must occur for a substance to be a good conductor.
- 5 Conductors are needed in electrical appliances, but so are insulators. Discuss reasons why insulators are used in electrical appliances, using an example.
- 6 Discuss how you made sure your observations and measurements during the investigation were accurate, and identify any real or potential errors.

Conclusion

Copy and complete:

'The results show that: (respond to the aim).'

Table INV8.5B: Results

Substance tested	Did light turn on? (Y/N)	Ammeter reading (A)	Conductor or insulator?

Exploring Ohm's law

Inquiry skill: Questioning and predicting

Inquiry skill focus: Developing a hypothesis

Part of a scientific investigation includes developing a hypothesis, which is a prediction of the outcome of an investigation that attempts to answer a question. To develop a hypothesis, you must first identify the independent, dependent and controlled variables. The independent variable is the one thing that you purposefully change in the investigation, the dependent variable is what you measure, and the controlled variables are all the things you keep the same throughout the investigation. Develop a hypothesis for this investigation, using the format below.

If ..., then ..., because ...

Hint 1: Identify and list your variables before drafting your hypothesis.

Hint 2: For help, refer to the Science how-to section on page 235.

Aim

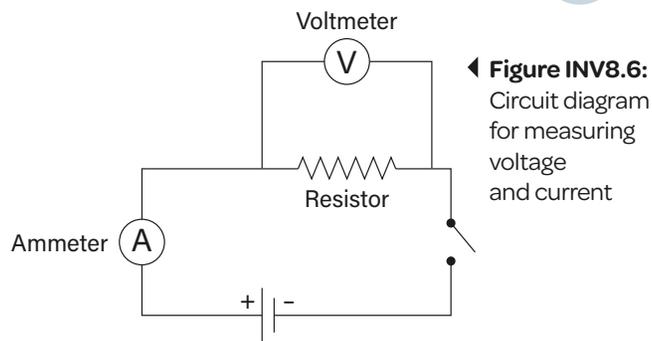
To investigate Ohm's law and determine the relationship between voltage, current and resistance

Materials

- fixed resistor (5–10 Ω)
- 0–12 V voltmeter
- 0–5 A ammeter
- variable DC power supply (2–12 V)
- 6 connecting wires with alligator clips

Method

- 1 Copy the results table into your notebook, adding a title.
- 2 Construct the circuit shown in the diagram but do not turn it on.
- 3 Set the power supply to 2 V and then turn on the power.
- 4 Close the switch. Note and record the readings on the ammeter and voltmeter in the results table.
- 5 Open the switch and increase the power supply by 2 V. Note and record the readings on the ammeter and voltmeter.



◀ **Figure INV8.6:** Circuit diagram for measuring voltage and current

- 6 Continue increasing the power supply by 2 V, and recording the readings, until the results table is complete.

Questions

- 1 Construct a graph plotting current (y -axis) against voltage (potential difference) (x -axis), using the data from your results table. Be sure to include a suitable scale for each axis, and labels on each axis, including units for each measurement.
- 2 Add another column to your results table and calculate the resistance, using your results.
- 3 Explain what the gradient of the line in the graph represents.
- 4 Outline what 'potential difference' means, in terms of what you measured.
- 5 Outline the relationship between voltage, current and resistance in a circuit.
- 6 Discuss any difficulties you had in completing this investigation and suggest how it could be improved.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Table INV8.6: Results

Power supply voltage (V)	Potential difference (voltmeter reading) (V)	Current (I) (ammeter reading) (A)
2		
4		
6		
8		
10		
12		

Investigation 8.7

Series and parallel circuits

Inquiry skill: Evaluating

Inquiry skill focus: Supporting findings with evidence

The data and observations generated and processed in an investigation should always be explained in the discussion of a scientific report using scientific knowledge. (See the Science how-to section on page 252.)

Hint 1: Think about the scientific concepts that are important for the investigation.

Hint 2: Summarise the data and any trends shown in your results.

Hint 3: Explain the data and trends using scientific understanding. For example: 'The results showed that ... This is because ...'

Aim

To measure and compare the voltage and current in series and parallel circuits

Materials

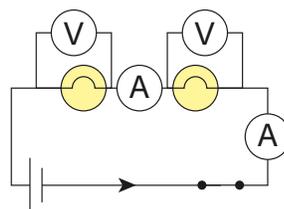
- 2 ammeters
- 2 voltmeters
- 9 electrical leads
- 4 × globes of the same size
- power pack or battery

Method

- 1 Copy the results table into your notebook, adding a title.
- 2 When you set up the circuits shown in Figures INV8.7a and INV8.7b, ensure that all globes are the same brightness. Ideally, set up both circuits at the same time, so that you can compare their brightness.

Part A: Series circuit

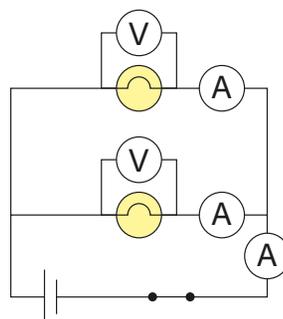
- 3 Set up the circuit as shown in Figure INV8.7a.
- 4 Note the brightness of the bulbs and record your observations.
- 5 Gently unscrew one bulb from the holder and record your observations. (**Caution: Check if bulbs are hot before touching them.**)
- 6 Measure and record the voltage across the power supply or battery.
- 7 Measure and record the voltage across each bulb.
- 8 Measure and record the current at two different points in the circuit.



◀ **Figure INV8.7a:**
Series circuit for Part A

Part B: Parallel circuit

- 9 Set up the circuit as shown in Figure INV8.7b.
- 10 Note the brightness of the bulbs and record your observations.
- 11 Gently unscrew one bulb from the holder and record your observations. (**Caution: Check if bulbs are hot before touching them.**)
- 12 Measure and record the voltage across the power supply or battery.
- 13 Measure and record the voltage across each bulb.
- 14 Measure and record the current in the main part of the circuit where the battery is.
- 15 Measure and record the current in each branch of the circuit.



◀ **Figure INV8.7b:**
Parallel circuit for Part B

Table INV8.7: Results

	Observations and results	
	Series	Parallel
Observation: brightness		
Observation: bulb removed		
Voltage over battery or power supply (V)		
Voltage over bulb 1 (V)		
Voltage over bulb 2 (V)		
Current at point 1 (A)		
Current at point 2 (A)		
Current in main part of circuit (A)		
Current in branch 1 (A)		
Current in branch 2 (A)		

Questions

- 1 Identify the main forms of energy involved in this investigation.
- 2 Identify and describe the energy transfers and transformations occurring in the investigation.
- 3 When one bulb was removed from its holder, explain why only one bulb goes out in a parallel circuit but both go out in a series circuit.
- 4 Describe the relationship between the voltage of the power supply and the voltage across both light bulbs in:
 - a a series circuit.
 - b a parallel circuit.
- 5 Compare the current measured in the series circuit and in the parallel circuit.
- 6 Discuss any relationship between the brightness you observed and the measurements taken.
- 7
 - a If these circuits were running off a battery, predict which circuit (series or parallel) would run the battery down the fastest.
 - b Justify your answer to part a using your observed results.

Conclusion

Copy and complete:
 'The results show that: *(respond to the aim).*'

Investigation 8.8

Short circuits

TEACHER DEMONSTRATION

Inquiry skill: Questioning and predicting

Inquiry skill focus: Making predictions

A key component of first-hand investigations is making a prediction of the outcome of the investigation.

You may not know much about the concepts under investigation yet, so sometimes it is okay to make a prediction based on what you have experienced and observed. Each part of the method asks you to make a prediction before you test.

Hint 1: Think about how current flows by the path of least resistance in a short circuit.

Hint 2: More information about making predictions is available in the Science how-to section on page 232.

Aim

To investigate a short circuit and how a fuse works

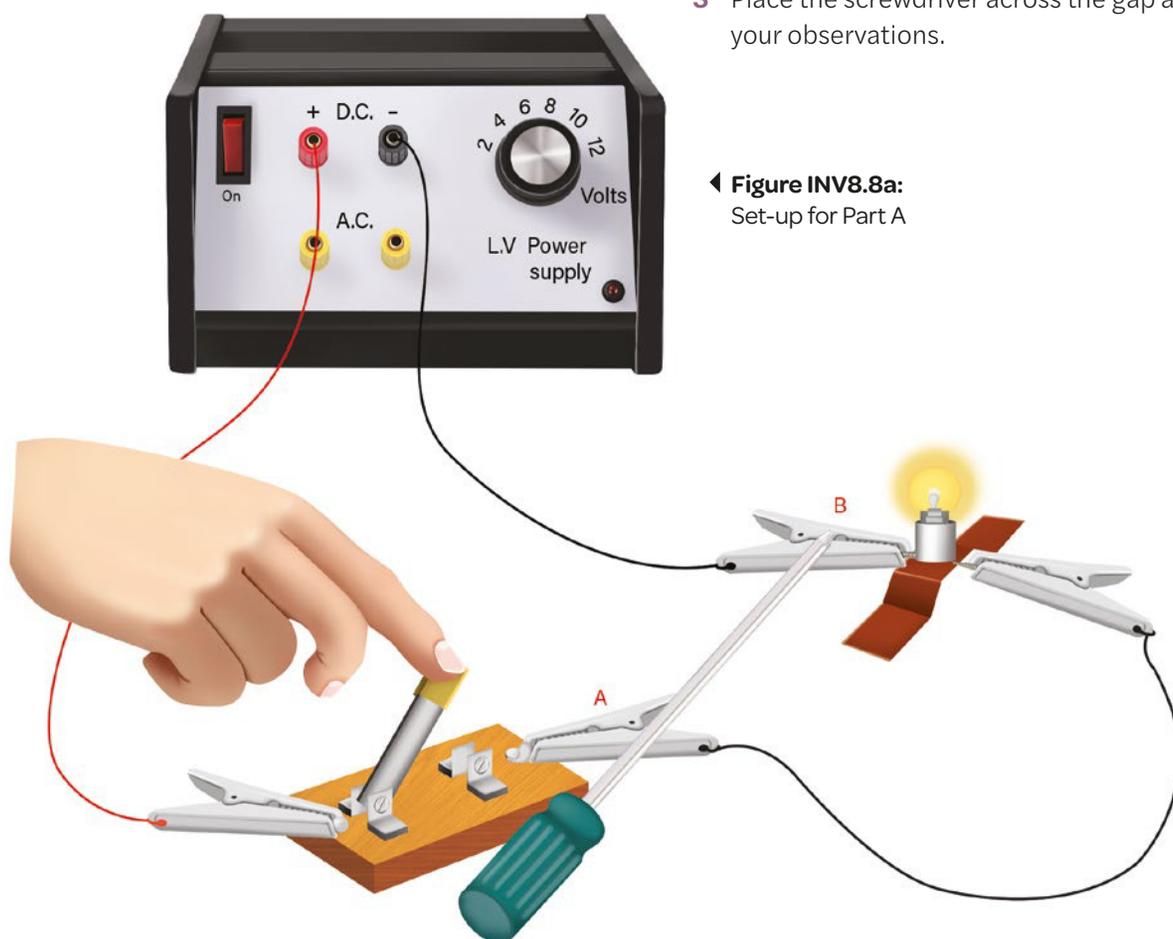
Materials

- power supply
- light bulb
- screwdriver or piece of metal
- rubber stopper
- 2 pins
- wires
- switch
- safety mat
- steel wool

Method

Part A: Making a short circuit

- 1 Set up your equipment as shown in Figure INV8.8a.
- 2 Before you place the screwdriver across the gap, predict what will happen when you do and write down your prediction.
- 3 Place the screwdriver across the gap and record your observations.



◀ **Figure INV8.8a:**
Set-up for Part A



◀ **Figure INV8.8b:**
Set-up for Part B

Part B: Testing a fuse

- 4 Set up your equipment as shown in Figure INV8.8b.
- 5 Before you place the screwdriver across the gap, predict what will happen when you do and write down your prediction.
- 6 Place the screwdriver across the gap between points A and B and record your observations.
- 7 If nothing happens, turn up the power pack voltage slightly.

Questions

Part A:

- 1 Describe the flow of electrons (the current) before and after the short circuit.
- 2 Describe what a short circuit is.

Part B:

In Part B of the investigation, you created and tested a fuse. A fuse is a small piece of wire that burns out when current is too high.

- 3 Explain how a fuse works in a similar way to how a circuit breaker works in a household electricity system.
- 4 Explain why you may have had to turn up the current power pack to blow the fuse.
- 5 Outline why a rubber stopper is used to hold the fuse.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Glossary

A

accuracy: how close a measured value is to the true, exact value; how closely a recorded value matches the expected outcome of an investigation

acidic: having properties of an acid (for example, corrosive); turns blue litmus paper red

aerobic respiration: the process of turning glucose into energy where the cells take in oxygen and release carbon dioxide

alloy: a metal mixed with another element

alternating current (AC): current that constantly changes direction

ammeter: a device that measures electric current

anaerobic respiration: how living things produce energy without oxygen

andesitic hornfels: a dark, fine-grained metamorphic rock known for its distinct green colouring and hardness

anomalies: data points or findings that do not follow the normal trend or expected findings

antiseptic: a substance that kills or stops the growth of germs such as bacteria, viruses and fungi

aorta: the main artery that leads from the heart to the rest of the body

artery: a type of blood vessel that carries blood away from the heart

asthenosphere: the portion of Earth's mantle underneath the lithosphere that can flow

adenosine triphosphate (ATP): the chemical energy made in cell organelles that living things use to carry out functions

atmosphere: the layer of gas that surrounds Earth

atom: particle that makes up all matter; made up of protons, neutrons and electrons

atomic mass: the mass of an atom of a chemical element

atomic number: the number of protons in an atom, used to organise elements into the Periodic Table

atomic theory of matter: a theory proposed by John Dalton that all matter is made of atoms

atria: filling chambers of the heart

attractive force: a force that pulls objects towards each other

audit: an investigation carried out in order to form an opinion based on a set of principles or guidelines

B

ball-and-stick model: a model that represents atoms as balls and bonds as sticks, making it easy to see how atoms are connected and arranged in space

basic: having properties of a base, opposite to an acid; turns red litmus paper blue

bile: a salty solution stored in the gallbladder, which aids digestion in the upper small intestine

binding agent: a substance that holds other materials together to form a cohesive whole

blood vessel: a tube such as a vein or artery that carries blood in the body

brass: an alloy made of copper and zinc

brittle: not able to be bent; will break or shatter if stressed

bronze: an alloy made of copper and tin

C

capillary: the smallest type of blood vessel

cardiovascular: related to the heart (cardio) and blood vessels (vascular)

cartographer: a person who makes maps

cell: the smallest functional unit of an organism

cell membrane: a thin layer around a cell that controls which substances enter and leave the cell

cell wall: a stiff layer around a plant cell that supports it

cellular respiration: the process of turning glucose into energy for cells to use

chemical bond: a force that joins atoms together in a molecule or compound

chemical change: a change in properties, so that a new substance is formed

chemical digestion: breaking down food in a chemical reaction that forms new molecules

chemical formula: an expression of the elements that make up a chemical compound, usually presented as a ratio using chemical symbols and numbers – for example, H₂O

chemical reaction: a process in which one or more substances are changed to form new substances; a rearrangement of the way atoms are joined

chemical sedimentary rock: sedimentary rock formed from layers of mineral crystals that have crystallised from water

chemical symbol: a letter or pair of letters used to represent a chemical element

chlorophyll: the green pigment in plant cells that absorbs sunlight and enables photosynthesis

chloroplast: a small organelle in a plant cell that makes food for the plant

chyme: a soupy mixture of partially digested food in the stomach and small intestine

circuit: a closed path for transferring electricity, including connecting wires and components connected to a power source

circuit breaker: a device that cuts off electricity if there is a short circuit

clastic sedimentary rock: sedimentary rock made of sediments cemented together

colloid: a mixture made of tiny insoluble parts

component: a device in a circuit that uses and transforms electrical energy

compound: a combination of two or more different elements, joined together in a fixed ratio

concave: hollowed or rounded inwards

conduction: the transfer of energy through a substance

conductivity: the ability to transfer energy by conduction

conductor: a substance that allows the transfer of energy or the movement of charge

conservation of mass: the scientific law that states that mass cannot be created or destroyed

consumption: use of a resource, such as energy

contact metamorphism: the process of change that happens to rock over small areas, often near volcanoes

continental drift: the theory that the continents have moved position over time

controlled variable: variable in an investigation that must be kept the same for all trials. Only the independent variable should change, otherwise it is not a fair test

convection: the transfer of energy by movement of a liquid or gas

convergent boundary: where two tectonic plates are moving towards each other and colliding

conversion factor: a number used to change one unit of measurement to another

core: Earth's central layer, made up of a liquid outer core and a solid inner core

correlation: a relationship between two factors or variables that shows them changing together, in either the same or opposite way

crust: Earth's thin outer layer, made up of continental crust and oceanic crust

crystal: a solid substance made up of very ordered microscopic parts

crystalline: having the structure and form of a crystal

cultural burning: the controlled use of fire by First Nations Peoples to care for Country

current: a measure of the flow of charged particles such as electrons in a circuit

cytoplasm: a jelly-like fluid inside a cell

D

data: facts and information collected for reference or analysis

data point (datum): a single identified element in a dataset

dataset: a collection of data, often from numerous trials related to a single factor

density: how heavy something is for its size; mass divided by volume

dependent variable: the thing that is measured in a first-hand investigation

deposition: a process in which sediment is left in a new place

diaphragm: the band of muscle under the lungs that enables the physical action of inhalation and exhalation

differentiate: to change so as to have a particular function

differentiated cell: a cell that has a specialised function

diffuse: to move from an area of high concentration to an area of low concentration

digestion: the physical and chemical processes that break down food in the body

direct current (DC): current that only flows in one direction

divergent boundary: where two tectonic plates are moving away from one another

DNA: the genetic information inside a body's cells

double glazing: insulation for windows using two panes or layers of glass

ductile: can be drawn out into a wire

E

earth wire: a wire that connects household electricity circuits to the earth

efficiency: a measure of how much useful energy is produced compared to how much is input into a system

electric field: an area around a charged particle in which it exerts a force on other charged particles

electrically neutral: having an equal number of protons (positively charged) and electrons (negatively charged)

electricity: the movement of charged particles

electrolysis: passing electricity through a substance to break it up

electromagnet: a magnetic field produced by electricity

electron: a subatomic particle that orbits the nucleus of an atom; it is negatively charged

electrostatic charge: the electric charge on the surface of an object

electrostatic force: an indirect force between any objects with an electric charge

electrostatic shock: the rapid movement of charged particles from one object to another

element: a pure substance made of only one type of atom

ember: a hot, glowing piece of wood produced during fire starting

embryonic stem cell: an undifferentiated cell that is collected from an embryo

endothermic: a reaction that absorbs energy in the form of heat

energy: the ability to do work

energy consumption: the amount of energy used, measured in kilowatt-hours (kWh)

energy input: the total amount of energy being put into a system

energy output: the total amount of energy coming out of a system

energy tariff: the price of electricity purchased from the electricity company, in cents

enzyme: a substance that enables or speeds up a chemical reaction

epicentre: the point on Earth's surface directly above the focus of an earthquake

epidermis: the outer layer of cells

equation: a mathematical statement that shows that two things are equal; for example, $2x + 6 = 14$ is an equation that needs to be solved so that $2x + 6$ does actually equal 14

erosion: a process in which sediments are moved from one place to another

ethical: relating to principles about what people think is 'wrong' and 'right'; in science, minimising harm to those involved, and ensuring investigations are conducted honestly and data is collected and recorded accurately

eukaryote: an organism with a nucleus and complex structures inside its cell(s)

evaluate: judge value based on scientific evidence

excretion: the elimination of cellular waste from the body through urine

exothermic: a reaction that releases energy in the form of heat

exponent: the superscript value to the right of a number that says how many times to use the number in a multiplication; for example, when we write 10^3 , '3' is the exponent. It means we need to multiply 10 by itself 3 times

extrusive igneous rock: igneous rock formed at Earth's surface

F

fair test: a test where all variables are kept the same, except for the independent variable and the dependent variable

fault: a break or an area of breaks between two blocks of rock

fermenting: the process where microorganisms chemically break down food into new substances

fibre: a thread from animal, plant or human-made material

field line: a line used to show the direction of a force within a field

fire: a self-sustaining chemical reaction between wood (or other material) and oxygen in the air that releases chemical energy as heat and light

flammable: catches fire easily when exposed to a spark or flame

focus: the origin of an earthquake

fossil: preserved remains or traces of once-living things

fossil record: the history of life on Earth as documented by fossils

fossilisation: the process of the formation of a fossil

friction: the force between two objects or surfaces when they push against each other

G

gas exchange: the exchange of oxygen and carbon dioxide between an organism and the environment

generate: produce

geological history: how Earth has changed over time

glomerulus: a bundle of capillaries; the filtering unit within each nephron

glucose: a type of sugar that is the energy source for cells

greenhouse gases: gases in the atmosphere that trap heat and contribute to the greenhouse effect, which warms the planet

groundwater: water held underground in porous rock and soil

H

hazard: something that can harm living things, objects or the environment

heat: the flow of thermal energy between objects

heat pump: a device that moves heat from one place to another

heterogeneous: a mixture with an uneven (non-uniform) composition

hiccups: when the diaphragm contracts involuntarily and repeatedly to produce a vocal 'hic' sound

homogeneous: a mixture with an even (uniform) composition

hormone: a chemical substance produced by the body that controls the activity of certain cells or organs

hotspot (shield) volcano: a volcano formed by magma upwelling underneath a tectonic plate

hypothesis: a suggested explanation or prediction of a scientific problem that can be tested with an investigation

I

igneous rock: rock formed from the solidification of molten rock (lava or magma)

impure substance: two or more different substances mixed together without a fixed chemical makeup

independent variable: the thing that is deliberately changed in a first-hand investigation

infer: to make an informed guess or conclusion based on evidence such as observations

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

insoluble: unable to dissolve

insulation: a material or substance that does not allow heat to pass easily through it

insulator: a material that resists the movement of charge or the transfer of thermal energy

intensity: a measure of the amount of destruction caused by an earthquake

intraplate earthquake: an earthquake that takes place in the middle of tectonic plates

intrusive igneous rock: igneous rock formed under Earth's surface

J

joules: the unit for energy, represented by the symbol J

K

kinetic energy: the energy of movement

L

lattice: a three-dimensional structure made of a repeating pattern of atoms or particles

lava: molten (melted) rock above Earth's surface

law of superposition: older rocks are found beneath younger rocks in a sequence

leaching: the process of soaking and rinsing away unwanted (soluble) chemicals from a substance

lime: a white powder (calcium oxide) made through a chemical change that removes carbon dioxide from the calcium carbonate contained in plant matter or seashells

lithosphere: Earth's rigid outer zone (crust and most of the upper mantle), made up of tectonic plates

litmus paper: special paper used to test whether a substance is acidic or basic by the colour; red = acidic, blue = basic

live or active wire: carries the electricity to the home

load: a component of a circuit that uses and transforms electrical energy

M

magma: molten (melted) rock under Earth's surface

magnetic field: an area around a magnet in which it exerts a force on other objects

magnetic force: an indirect force that affects any object made of certain metals

magnitude: a measure of the energy released by an earthquake

malleable: able to be bent and shaped

mantle: Earth's middle layer, made up of an upper mantle and a lower mantle

mass: the amount of matter something contains, often measured in grams (g)

mass per cent: the ratio of the mass of a part of a mixture, relative to the total mass, expressed as a percentage

mathematical formula: a rule or principle that helps you to find the answer to a question or understand the relationship between variables

matter: any substance that has mass and takes up space

mean: a measure of centre (an average) calculated by adding all the numbers together and dividing by how many numbers there are

mechanical digestion: physically breaking down food into smaller pieces

median: the middle number in a set of numbers when they are arranged in order

meniscus: the curve seen at the top of a liquid in its container

metalloid: an element with properties of both metals and non-metals

metamorphic rock: rock formed from another rock that has been changed by heat or pressure, or both

metamorphism: the process of change that happens to a rock because of heat or pressure, or both

mid-ocean ridge: a long chain of mountains under the ocean formed by plate tectonics

mineral: a naturally occurring inorganic (non-living) substance

mitochondria: a complex, oval-shaped organelle that produces ATP energy through the process of respiration

mixture: two or more substances that are combined but can be physically separated

mode: the number that appears most frequently in a set of numbers

model: a simplified way of explaining something complex and real based on evidence

molecular elements: molecules made up of more than one of the same type of atom

molecular formula: an expression of the number and types of atoms in a single molecule of a compound

molecule: two or more atoms chemically bonded together; the smallest unit of a chemical compound

motion: the change in position of an object over time

multicellular: made of more than one cell

N

nephron: a microscopic filtration structure in the kidneys that removes waste and excess water

neutral wire: completes the household circuit back to the power supply

neutron: a subatomic particle located in the nucleus of an atom; it is neutrally charged

Newer Volcanics Province: an area covering roughly 15 000 square kilometres in south-east Australia; the continent's most recent active volcanic area

Nobel Prizes: world-famous awards given each year for academic, cultural and scientific advances

non-flammable: does not catch fire easily when exposed to a spark or flame

nucleus: the centre of an atom, which contains protons and neutrons; the control centre of a cell; contains DNA

O

ochre: an earth-based pigment containing iron(III) oxide used for thousands of years by First Nations Peoples for painting, art and ceremony

Ohm's law: a scientific law which demonstrates that the current through a conductor between two points is directly proportional to the voltage across the two points

optimise: make the most effective use of something

organ: a structure made up of two or more tissues that has a specific function

organ system: two or more plant or body organs that are connected and working together

organelle: a structure within a cell

organic sedimentary rock: sedimentary rock formed from the remains of plants or animals

organism: an individual animal, plant or other living thing

P

parallax error: the apparent shift in something's position when it is viewed from different angles

parallel circuit: a circuit in which all components are connected between the same points in branches, so the current divides into more than one path

particle model diagram: shows the arrangement and movement of particles in a substance

particle theory: all matter is made up of tiny particles; a model used to explain the properties of solids, liquids and gases based on the arrangement and movement of particles

pattern (data): when data repeats in a predictable way

pendulum: an object suspended at the end of a string that swings back and forth

perinatal: the time and areas around birth

periodic table: a table of elements arranged periodically in a table based on their properties

Periodic Table: a table of the chemical elements arranged in order of atomic number from 1 to 118

periodicity: quality of being periodic; the tendency for something to occur repeatedly or in patterns

peristalsis: the involuntary muscle action that pushes food through the digestive tract

phloem: a tubular structure that transports food around a plant

photosynthesis: the chemical reaction, powered by sunlight, in plants that converts carbon dioxide and water into sugar and oxygen

physical change: a change in appearance, with no new substance formed

physical property: a characteristic or attribute of a substance that can be observed and measured, such as colour, texture, melting and boiling points, density and hardness

pistil: the female reproductive part of a flower (the stigma, style and ovary)

plagiarise: to copy someone else's work and present it as your own

plausible: could be reasonably accepted based on available evidence

pollen: the fine powder produced by the male part of a flower; contains male sex cells

pollination: the movement of pollen from the male part of a flower to the female part (from the anther to the stigma)

potential difference: the difference in potential energy (voltage) between two points in a circuit

potential energy: stored energy; has the ability to cause movement

power: the end product obtained by multiplying a quantity by itself one or more times; for example, 2 to the power of 3 is $2 \times 2 \times 2$, which is 8, so the power of 2^3 is 8

precipitate: a solid that forms in a solution

precision: how close measured values are to each other within a dataset

product: a substance formed in a chemical reaction

prokaryote: a simple organism that does not have a nucleus

property: characteristic of a substance that can be observed

proton: a subatomic particle located in the nucleus of an atom; it is positively charged

protozoan: a unicellular eukaryote that moves and feeds on organic matter

pure substance: matter that has a fixed chemical makeup

pyrophytic: plants that have adapted to fire

R

radial field: a field in which the field lines radiate from a centre

radiation: the transfer of energy that does not require contact with matter

range: in a set of numbers, a measure of spread between the highest number and the lowest number

ratio: a way of comparing like quantities without units

raw data: data that is collected directly from the investigation

reactant: a substance that undergoes a chemical change

reflect: to bounce thermal or solar energy off a surface

regional metamorphism: the process of change that happens to rock over large areas

relationship: a link between two factors

relative age: the approximate age of a rock determined by comparing it to another rock

renal: an adjective that means 'related to the kidney'

repulsive force: a force that pushes objects away from each other

resistance: a measure of the opposition to flow of electric current

respiration: a chemical reaction that converts glucose to energy

reversible: can be changed back to its previous state

ribosome: a small, simple organelle that produces proteins

rift valley: a valley formed when a continent is being pulled apart

S

scale factor: the ratio between corresponding measurements of an object and a copy of that object

scientific notation: a way to write very large or very small numbers in a simple form

scientific theory: an explanation of a natural phenomenon that is supported by evidence and the results of repeated tests

sediment: small particles of rock, such as clay, sand and pebbles

sedimentary rock: rock formed by sediments that have been pressed together

seismic data: data relating to earthquake waves

seismic wave: a wave of energy that passes through Earth's layers and is caused by an earthquake

seismometer: a scientific instrument that detects seismic waves

sequence: the order of something

series circuit: a circuit in which components are connected in a line, so the current has only one path to take

short circuit: when a fault occurs that creates a low-resistance pathway through which current flows

solar: from the Sun

solidify: become a solid

solute: a substance that is dissolved by a solvent

solution: a mixture made up of a solute and a solvent

solvent: a substance that a solute dissolves in

space-filling model: a model that shows how molecules might appear if magnified

splint: wooden stick that can be lit to provide a flame or glowing tip

stamen: the male reproductive part of a flower (the anther and filament)

star rating: a rating for comparing the efficiency of different appliances

steel: an alloy made of iron and carbon

stem cell: an undifferentiated cell that occurs throughout the body and can develop into various types of cells

stomata: pores on the surface of a leaf; the site of gas exchange in plants

strato volcano: a volcano formed at a subduction zone

structural formula: a representation of a compound or molecule that shows how atoms are chemically joined to one another

subatomic particles: particles that make up atoms: protons, neutrons and electrons

subduction: when one tectonic plate moves underneath another

subscript: a letter or number written slightly below and to one side of another; for example, '2' in H₂O

superscript: a letter or number written slightly above and to one side of another; for example, '2' in 8²

surface tension: where the molecules at the surface of a liquid are more attracted to each other than to the air above the liquid

suspension: a mixture made of large insoluble parts

system: a set of simple things that work together to perform a function

T

tectonic plate: a section of Earth's lithosphere

thermal energy: a type of kinetic energy (heat energy) indicated by temperature

thermoplastic: a substance that becomes plastic when heated and hardens when cooled, and can undergo these processes repeatedly

tinder bundle: a small amount of fine dry grass, animal dung, leaves or other matter used to start a fire

tissue: a group of cells with a similar structure and function

transfer: the movement of energy from one place or object to another

transform: the change of energy from one form to another

transform boundary: where two tectonic plates slide past each other

trend (data): when data moves in a general direction, usually up or down

true value: the actual, exact value of a measurement, error-free, which would be obtained if a perfect measurement were made

tsunami: a sea wave caused by the displacement of water as a result of an earthquake or other disturbance

tubule: a small tube made of epithelial cells

U

undifferentiated: has not changed from its original form

unicellular: made of one cell

urea: a product of the chemical breakdown of food, specifically proteins

useful energy: the energy output from a system that is able to be used for a purpose

V

vacuole: an organelle used for the storage of waste (animals) and water (plants)

vacuum: a space that has no matter

validity: when an investigation meets its intended purpose

variable: a factor in an investigation or a model that can be changed, measured or controlled

vascular tissue: tissue that transports fluid and nutrients throughout a plant

vein: a type of blood vessel that returns blood to the heart

vena cava (plural venae cavae): the main vein that leads to the heart from the rest of the body

ventricles: pumping chambers of the heart

villi: the tiny finger-like projections that line the walls of the small intestine

volcano: a point in Earth's crust where lava erupts

voltage: a measure of electric potential energy

voltmeter: a device that measures potential difference (voltage)

W

weathering: a process in which rocks are worn down into smaller particles

word equation: a representation of a chemical change in words

work: when a force applied to an object causes the object to move

X

xylem: a tubular structure that transports water and nutrients from the roots to various parts of a plant

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