Good Science

NSW Stage 5

Second Edition

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Acknowledgement of Country

We acknowledge the Aboriginal and Torres Strait Islander Peoples of this nation. We acknowledge the Traditional Custodians on whose unceded lands we have created this resource. We pay our respects to ancestors and Elders past and present.

Note about language

Please note that we use the terms ‘Aboriginal and Torres Strait Islander’ and ‘First Nations’ interchangeably. We acknowledge that there is no one term that is universally accepted and we use these terms with respect.

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Learning Ladder for NSW Stage 5

Steps in progression	Energy	Disease	Materials	Environmental sustainability	Genetics and evolutionary change	Reactions	Waves and motion	Data science 2
5	I can evaluate the use of current and alternative energy options.	I can analyse a range of disease prevention and management strategies for their effectiveness.	I can evaluate how materials are sourced, used and modified.	I can analyse how human activity has impacted the natural world.	I can evaluate evidence of how the diversity of life has changed over time.	I can analyse the real-world implications of reactions used in different industries.	I can analyse our understanding of waves and motion and their impacts on society.	I can assess the use of datasets to verify scientific claims.
4	I can discuss methods of energy transformation and use.	I can interpret data relating to body balance and health, and disease incidence and prevalence.	I can discuss the impact of various materials on the environment.	I can discuss a range of factors that can impact the natural world.	I can discuss how a range of organism characteristics provide evidence of genetic inheritance patterns and change.	I can apply my understanding of reactions to represent changes that take place.	I can quantify and compare the features of waves, and analyse and calculate mathematically an object's motion.	I can discuss the features of datasets and link these to their uses.
3	I can explain changes to energy and energy efficiency.	I can explain how processes and functions can maintain balance and health or cause disease.	I can explain the uses of materials based on their properties.	I can explain the impacts of natural phenomena and human-influenced processes on the environment.	I can explain how genetics can be examined and manipulated using different technologies.	I can explain how different factors affect reactions.	I can explain the applications of waves and the motion of objects.	I can explain how data can help to support scientific claims.
2	I can describe sustainable and non-sustainable energy practices.	I can describe how specific mechanisms work to maintain balance and health in the body or cause disease.	I can describe materials based on bonding and properties.	I can describe the effects of natural and man-made products on the natural world.	I can describe how characteristics of organisms have been inherited, and changed, over time.	I can describe changes that occur in a range of reactions.	I can describe and compare the properties of waves and of objects in motion.	I can describe how data can be used in a number of different ways.
1	I can identify a range of energy types and sources.	I can identify mechanisms that help to maintain balance and health or cause disease.	I can classify different types of materials.	I can make observations about the natural world and things that impact it.	I can identify a range of characteristics relating to the genetics and evolution of organisms.	I can identify different types of reactions.	I can identify features of waves and of objects in motion.	I can identify scientific claims and data.
	SC5-EGY-01	SC5-DIS-01	SC5-MAT-01	SC5-ENV-01	SC5-GEV-01 SC5-GEV-02	SC5-RXN-01 SC5-RXN-02	SC5-WAM-01 SC5-WAM-02	SC5-DA2-01

Content

I can select scientific equipment to improve the precision of my observations.	I can evaluate questions and hypotheses relating to scientific phenomena.	I can assess the type of data that can be collected in a range of investigations.	I can extract data from secondary sources and construct appropriate references to acknowledge their use.	I can evaluate investigations based on the quality of processed data.	I can evaluate conclusions based on the quality of data.	I can evaluate scientific claims based on evidence.	I can evaluate scientific findings based on secondary evidence and arguments.	5
I can use observations and measurements to answer questions.	I can formulate testable questions and predictions, considering variables and controls.	I can produce plans for investigations that are ethical, reliable and valid.	I can accurately collect and record data, information, evidence and findings from first-hand and second-hand investigations.	I can use data to support or refute questions, hypotheses or solutions to problems.	I can assess data and information for accuracy, reliability and validity.	I can assess problem-solving strategies used to solve an identified problem.	I can present scientific findings using appropriate conventions for specific audiences.	4
I can make inferences based on my observations.	I can propose hypotheses based on scientific knowledge.	I can develop appropriate scientific aims for a range of investigations.	I can conduct first-hand investigations and accurately record the collected data and identify errors.	I can process and interpret quantitative and qualitative data from a range of sources.	I can draw conclusions based on patterns in data and information.	I can use given criteria to find solutions to scientific problems.	I can construct a range of appropriate scientific presentations based on first-hand and second-hand data and information.	3
I can record observations and measurements accurately.	I can construct questions to investigate scientific concepts or problems.	I can distinguish between controlled, dependent and independent variables.	I can use scientific equipment to conduct investigations and gather first-hand data and information.	I can organise and represent data in appropriate ways, including in tables and graphs.	I can explain relationships between datasets and information.	I can explain scientific problems and phenomena using cause-and-effect relationships.	I can use digital technologies to organise and present data and information.	2
I can use scientific tools to enhance observations.	I can select questions to investigate scientific concepts or problems.	I can describe ways to reduce risks for a range of investigations.	I can implement safe practices when using scientific equipment.	I can select and extract information from various texts and sources.	I can describe trends from collected data and information.	I can propose solutions to familiar scientific problems.	I can select appropriate ways to communicate information.	1
Observing	**Questioning and predicting**	**Planning invest-igations**	**Conducting invest-igations**	**Processing data and information**	**Analysing data and information**	**Problem-solving**	**Commun-icating**	Steps in progression
SC5-WS-01	SC5-WS-02	SC5-WS-03	SC5-WS-04	SC5-WS-05	SC5-WS-06	SC5-WS-07	SC-WS-08	

Working scientifically processes

Stage 5 syllabus correlation grid

FOCUS AREAS	1.0 Energy	2.0 Disease
Content		
SC5-EGY-01: Energy Evaluates current and alternative energy use based on ethical and sustainability considerations	✓	
SC5-DIS-01: Disease Explains how an understanding of the causes of disease can be used to prevent and manage the spread of disease		✓
SC5-MAT-01: Materials Assesses the uses of materials based on their physical and chemical properties		
SC5-ENV-01: Environmental sustainability Analyses the impact of human activity on the natural world		
SC5-GEV-01: Genetics and evolutionary change Describes the relationship between the diversity of living things and the theory of evolution **SC5-GEV-02: Genetics and evolutionary change** Explains how DNA is responsible for the transmission of heritable characteristics and can be manipulated through genetic technologies		
SC5-RXN-01: Reactions Describes a range of reaction types **SC5-RXN-02: Reactions** Explains the factors that affect the rate of chemical reactions		
SC5-WAM-01: Waves and motion Describes the features and applications of different forms of waves **SC5-WAM-02: Waves and motion** Explains the motion of objects using Newton's laws of motion		
SC5-DA2-01: Data science 2 Assesses the use of scientific knowledge and data in evidence-based decisions and when verifying the legitimacy of claims		

Working scientifically processes		
SC5-WS-01: Working scientifically: Observing Selects and uses scientific tools and instruments for accurate observations	✓	
SC5-WS-02: Working scientifically: Questioning and predicting Develops questions and hypotheses for scientific investigation		
SC5-WS-03: Working scientifically: Planning investigations Designs safe, ethical, valid and reliable investigations		
SC5-WS-04: Working scientifically: Conducting investigations Follows a planned procedure to undertake safe, ethical, valid and reliable investigations	✓	
SC5-WS-05: Working scientifically: Processing data and information Selects and uses a range of tools to process and represent data		
SC5-WS-06: Working scientifically: Analysing data and information Analyses data from investigations to identify trends, patterns and relationships, and draws conclusions		✓
SC5-WS-07: Working scientifically: Problem-solving Selects suitable problem-solving strategies and evaluates proposed solutions to identified problems	✓	
SC5-WS-08: Working scientifically: Communicating Communicates scientific arguments with evidence, using scientific language and terminology in a range of communication forms		✓

3.0 Materials	4.0 Environmental sustainability	5.0 Genetics and evolutionary change	6.0 Reactions	7.0 Waves and motion	8.0 Data science 2
✓					
	✓				
		✓			
			✓		
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✓		✓			✓

Focus area 1

1.0 Energy

We often think of energy as something we have, such as energy to run, play sport or walk up a hill. Sometimes we feel as though our energy is running out. Where does that energy go?

When we use energy, it does not disappear – it turns into other forms of energy. In our bodies, energy is stored as chemical energy, which is turned into kinetic (movement) energy and heat. Other forms of energy are light, sound, nuclear and electrical energy. One form of energy can transform into other forms of energy.

Learning Ladder

The Learning Ladder contains the scientific content and processes you will learn in this focus area. Each area has five levels of progression. To move to higher levels, you need to practise activities at the earlier levels. This will help you develop the ability to complete tasks that are more complex.

Steps in progression	Content: Energy	Working scientifically processes: Observing	Working scientifically processes: Conducting investigations	Working scientifically processes: Problem-solving
5	I can evaluate the use of current and alternative energy options.	I can select scientific equipment to improve the precision of my observations.	I can extract data from secondary sources and construct appropriate references to acknowledge their use.	I can evaluate scientific claims based on evidence.
4	I can discuss methods of energy transformation and use.	I can use observations and measurements to answer questions.	I can accurately collect and record data, information, evidence and findings from first-hand and second-hand investigations.	I can assess problem-solving strategies used to solve an identified problem.
3	I can explain changes to energy and energy efficiency.	I can make inferences based on my observations.	I can conduct first-hand investigations and accurately record the collected data and identify errors.	I can use given criteria to find solutions to scientific problems.
2	I can describe sustainable and non-sustainable energy practices.	I can record observations and measurements accurately.	I can use scientific equipment to conduct investigations and gather first-hand data and information.	I can explain scientific problems and phenomena using cause-and-effect relationships.
1	I can identify a range of energy types and sources.	I can use scientific tools to enhance observations.	I can implement safe practices when using scientific equipment.	I can propose solutions to familiar scientific problems.

Figure 1.1: Skateboarding is all about energy.

1·1 ▸ The law of conservation of energy

Learning intention

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

- identify a range of energy types
- apply the law of conservation of energy to account for the total energy involved in energy transfers and transformations.

Key terms

energy: a measure of the ability to do work

energy transfer: the movement of energy from one place to another without changing form

energy transformation: a change from one type of energy to another

law of conservation of energy: a scientific law which states that energy is never created or destroyed; it can only change into different forms

Investigation 1.1

Galileo's pendulum, page 473

Content group: Law of conservation of energy

Figure 1.2: For a toaster to toast bread, electrical energy is transferred from the power station to the toaster, where it is transformed into heat energy.

Many devices require energy. The energy may need to be transferred from one place to another and transformed from one type of energy into another. Transfers and transformations of energy are crucial for many systems to be able to operate effectively.

Energy is the ability to do work

Energy is the ability to do work. Energy can be found in many things and can take different forms such as heat and kinetic energy. Energy can also be stored. Stored energy is known as potential energy, because it has the potential to be transformed and do work.

Energy cannot be created or destroyed

The conservation of energy is a fundamental law of physics. The **law of conservation of energy** states that energy can never be created or destroyed; it can only change into different forms. This means that all the energy we use now existed in some form billions of years ago and has cycled around continuously.

There are different types of energy

Although energy cannot be created or destroyed, it can exist in different forms. Table 1.1 lists some types of energy.

Table 1.1: Types of energy

Type of energy	Description
Chemical	Energy stored in chemical bonds
Elastic potential	Energy stored in an object that has been stretched or compressed
Electrical	Energy that travels through electrical circuits
Gravitational potential	Energy stored in an object that has been raised to a higher point
Heat	Energy in the form of vibrating particles in solids, liquids and gases; measured as the change in temperature of an object
Kinetic	Energy of motion, which any moving object has
Light	Energy in the form of waves, emitted from a glowing object
Nuclear	Energy released from or stored in the nuclei of atoms
Sound	Energy in the form of vibrating particles in water, air or solids and transferred as waves

Figure 1.3: Elastic potential energy is stored in a drawn bowstring.

Energy can be transferred

A rolling marble has kinetic energy, and if it collides with a stationary marble, both marbles move away. An **energy transfer** has taken place from the first marble to the second marble.

Electrical energy is transferred from a power station, through power lines, to your house where it comes out of a power point and goes into appliances.

You can feel heat transfer – imagine touching a hot stove with your finger!

Energy can change form

Energy can transform, or change, from one form into another. **Energy transformations** can take place using technology, such as a toaster transforming electricity into heat, but they also happen naturally.

Figure 1.4 shows the transformations that take place when you throw a ball straight up in the air. Kinetic energy is transformed into gravitational potential energy, then back to kinetic energy and to sound and heat energy.

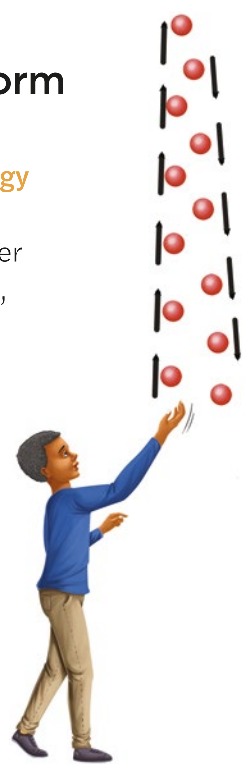


Figure 1.4: When a ball is thrown upwards, its energy is transformed.

Learning Ladder

Energy

1. Identify a device that can transform:
   - **a** electrical energy into light and sound energy.
   - **b** chemical energy into heat energy.
   - **c** light energy into chemical energy.
   - **d** chemical energy into kinetic energy.
2. Describe the law of conservation of energy.
3. Explain the difference between energy transfer and energy transformation, using examples.
4. Discuss the energy transformation when:
   - **a** a power station burns coal to produce electricity.
   - **b** a pot of water is placed on a gas stove to boil.
   - **c** a rubber band is stretched back and released.
   - **d** a skateboarder drops from the top to the bottom of a skate ramp.
   - **e** a person hits a tennis ball. (There is more than one transformation!)

Observing

see page 398

1. Identify the instrument and unit that are used to measure heat energy.
2. **a** What do you observe when you hold a snowball?
   b Based on this observation, identify the type of energy being transferred and the direction of energy transfer.
3. You observe an object fall off a shelf onto the floor and make a loud sound. What can you infer about the energy transformations that occurred?
4. Imagine the ball in Figure 1.4 was thrown twice as high. Describe how much energy would be required and how much energy the ball would have when it reached maximum height.
5. Discuss at least three observations you could make that show an energy transformation has occurred. Include the scientific equipment you could use to make these observations.

In context

A car is a machine that uses energy to do work. It can transform energy into many forms. Draw a picture of a car, and label at least five energy transformations that can occur. Think about both inside and outside the car.

Success criteria

- I can identify and describe a range of energy types.
- I can explain the law of conservation of energy, and describe examples of energy transfer and transformations that account for the total energy involved.

1·2 ► Energy efficiency

Learning intention

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

- explain and calculate energy efficiency in relation to energy transfers and transformations
- explain how to improve efficiency.

Key terms

efficient: not wasteful

energy efficiency: how much usable energy is produced compared to how much energy has been supplied

friction: a contact force that opposes motion; caused by objects rubbing against each other

joule: the unit of energy (J)

Investigation 1.2

Energy efficiency of bouncing balls, page 474

Content group: Law of conservation of energy

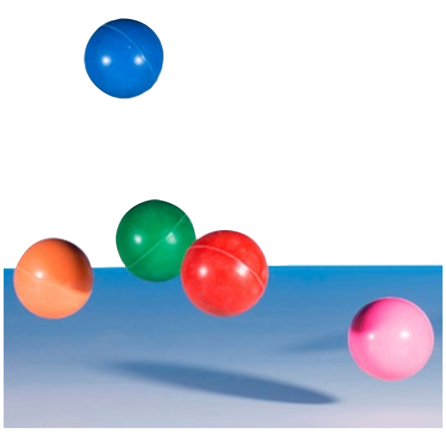


Figure 1.5: Rubber balls bounce higher than tennis balls because they lose less energy as heat and sound.

Imagine a perpetual motion machine that would continue forever, with no new energy required to keep it going and no energy wasted. This could only occur in an isolated system. Isolated systems are used as a model in science, but they do not occur in the real world. It is not possible to stop energy loss, and so a perpetual motion device is not possible.

Energy is lost in energy transfers and transformations

Energy is lost in energy transfers and transformations. A tennis ball falling from a height initially has gravitational potential energy. As the ball falls, the gravitational potential energy is converted into kinetic energy. When the ball strikes the ground, it compresses and stores elastic potential energy. The elastic potential energy is then transformed into kinetic energy as the ball bounces back up.

The ball never bounces back to its original height even though energy cannot be created or destroyed. With each bounce, the ball loses more energy.

- As the ball falls, air resistance (a form of **friction**) causes the ball to heat up slightly and some heat energy is transferred to air particles.
- As the ball strikes the ground, some of its kinetic energy is converted into sound energy.
- As the ball strikes the ground, a small amount of heat energy is transferred to the ground through friction.

All devices waste energy

Mechanical devices work by converting one type of energy into another. A device is usually designed to produce a particular type of energy output that makes an action occur. However, devices also waste energy. For example, a light bulb produces useful light energy, but it also loses some heat energy.

Moving objects can lose energy as heat because of friction. When you are riding your bicycle, the tyres warm up because of the friction between the tyres and the road. This 'lost' energy has been converted from usable kinetic energy into wasted heat energy.

Friction can also be helpful. Car brakes work through friction, which converts kinetic energy into heat.

Energy in devices can also be lost in other ways. A car loses energy through engine noise and heat. Most electrical devices lose energy as heat and sound.

Figure 1.6: A spacecraft re-entering the atmosphere experiences friction with the air, converting kinetic energy into heat.

All devices are less than 100 per cent energy efficient

We can determine how energy **efficient** a device is. Less energy waste equals more efficient energy use. The **energy efficiency** of a device is the amount of usable energy (energy output) divided by the amount of energy put into the device. The unit of energy is the **joule** (J).

$$\text{Energy efficiency (\%)} = \frac{\text{energy output}}{\text{energy input}} \times 100$$

When a smartphone is fully charged, the energy in the battery should be converted into light energy (on the screen) and sound energy (through the speakers). If the phone heats up, some of the potential energy from the battery is lost as heat energy, resulting in shorter battery life.

If a smartphone were 40 per cent efficient, then for every 100 J of energy in the battery, only 40 J would be transformed into light and sound, and 60 J would be lost as heat. If a smartphone were 80 per cent efficient, it would only waste 20 J as heat and so the battery would last much longer.

Energy loss can be reduced

It is possible to reduce energy loss. For example, slimmer, smoother tyres on a bike reduce friction and wasted energy. Making surfaces smooth, or using oil or grease, can reduce friction in a car engine.

Electrical circuits can be designed to be more efficient, and using insulation can help retain heat in a device such as a clothes dryer.

Learning Ladder

Energy

1. Identify two forms of energy that are common forms of wasted energy.
2. Describe an example of when friction is a problem, and an example of when it is useful.
3. Explain, in terms of energy, why a skateboard slows down as it travels.
4. Discuss the useful energy outputs that smartphones produce.
5. Propose two design changes that could make refrigerators more energy efficient.

Problem-solving

see page 425

1. Calculate the energy efficiency for an:
   a incandescent light bulb with 1000 J of energy input and 100 J of light output.
   b LED light bulb with 1000 J of energy input and 750 J of light output.
2. Explain which bulb in Question 1 is more efficient in terms of wasted energy.
3. Select the bulb in Question 1 that will cost less to run. Justify your answer.
4. For every 100 J of electrical energy put into a kettle, 40 J is lost as unwanted sound and heat. The packaging says that the efficiency is 40 per cent. Assess the accuracy of this claim by calculating the efficiency and comparing it to what the packaging says.

In context

Think of a device that is not very energy efficient. Redesign this device to increase efficiency, improving at least two things. Explain your improvements.

Success criteria

- I can describe how energy is lost in energy transfers and transformations.
- I can explain what is meant by 'energy efficiency', calculate energy efficiency, and identify ways to improve efficiency.

1·3 ▸ Sources of energy

Learning intention

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

- identify sources of energy
- describe how electrical energy can be produced from different energy sources and compare their efficiency.

Key terms

alternator: a device that converts kinetic energy into electrical energy

fossil fuel: an energy source made of ancient fossils

generate: to make or produce something

non-renewable: finite, and will run out

renewable: can be renewed, and will not run out

solar energy: energy from the Sun

Content group: Sources of energy

From the moment you wake up and turn on the light or heater, or check your smartphone, you are using electricity. Electricity, or electrical energy, is generated from other energy sources such as wind, coal or the Sun and this involves energy transformations and transfers.

Energy sources can be used to make electricity

Most energy sources can be used to **generate** electrical energy. The energy source is usually used to spin a turbine. For example, coal or gas can be burned to heat water, the water boils and becomes steam that moves quickly through pipes and is pushed through a turbine, making it spin. The spinning turbine spins the **alternator**, which converts the kinetic energy into electrical energy.

Solar energy can be used more directly to create electricity, by photons in the Sun's rays causing electrons in metal wires to move.

Some energy sources are renewable, some are not

Some sources of energy will run out and cannot be replaced – they are **non-renewable** (see Table 1.2). Most of Australia's electricity has been generated (produced) by burning **fossil fuels**. Fossil fuels take millions of years to form. They include coal, oil and gas, which are made from the bodies of dead animals and plants.

Figure 1.7: At a coal-fired power station, coal is burned to heat water to produce steam, which makes a turbine spin. This image shows inside a turbine. You can see the blades that steam is pushed over to make the turbine spin.

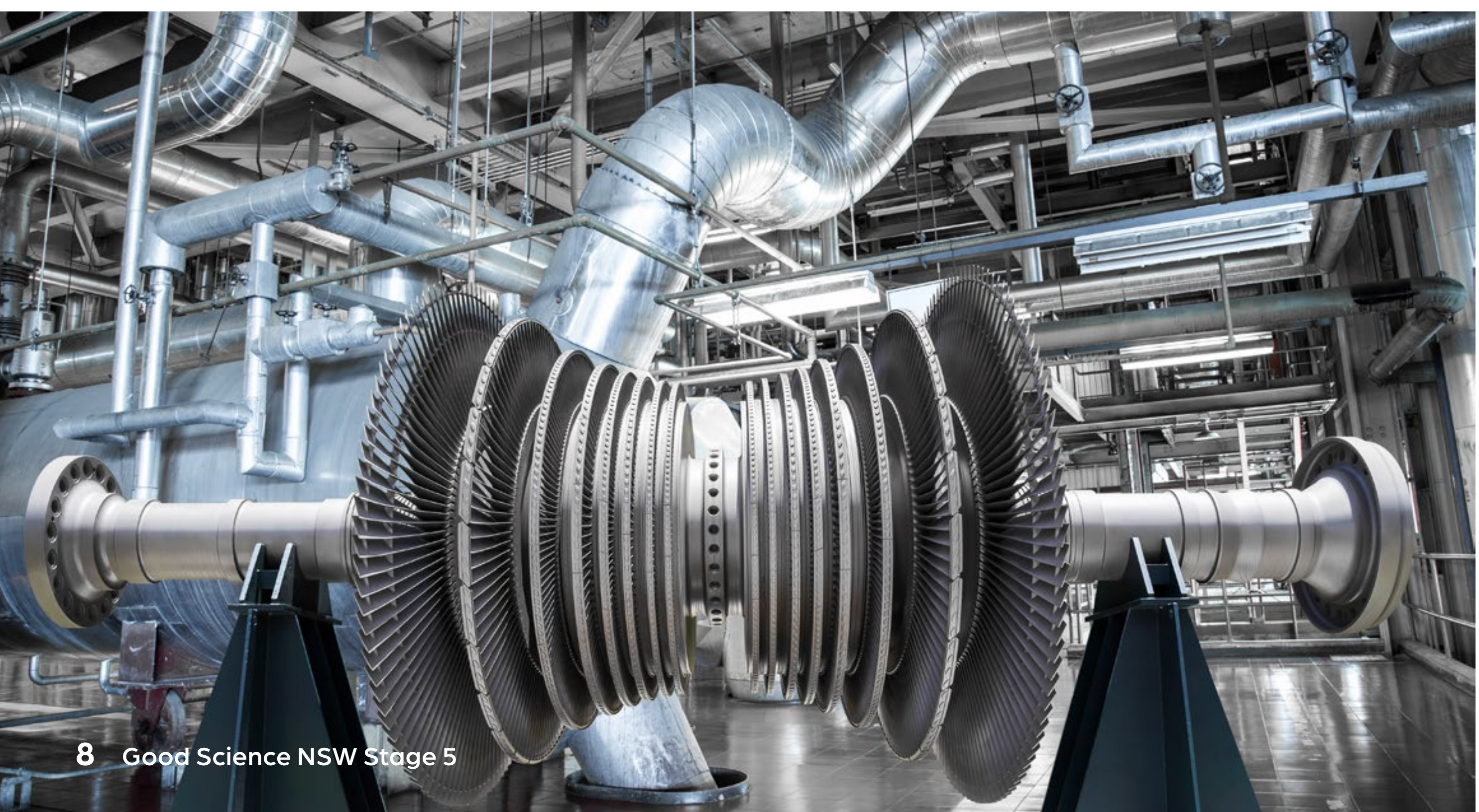


Figure 1.8: Australia has large solar farms, and small rooftop solar on buildings.

Renewable energy sources such as wind and solar energy will not run out (Table 1.3). Renewable sources of energy can be less reliable; for example, the wind does not always blow, so wind energy output is not always constant. Solar can only produce electricity during daylight, and less will be produced on cloudy days.

Australia is undergoing a conversion to increase the use of renewable energy. For example, the government has payments to help people change over to solar power, and in some cases batteries for power storage. Some people are reluctant to accept the change to more renewable energy. For example, some farmers do not want wind turbines on their property, as they can harm wildlife such as migrating birds. There are many ways we can change our energy supply and use in Australia, and this will require public debate about the best ways forward.

Table 1.2: Non-renewable energy sources

Energy source	Description	How electricity is generated
Gas, oil	Chemical energy stored in a gas or liquid (oil), made from ancient living things	Gas, oil or coal is burned to heat water, which becomes steam, which spins a turbine and an alternator, generating electricity. Oil can be separated into petrol and diesel, which can be burned inside an engine to produce kinetic energy.
Coal	Chemical energy stored in the form of a rock, made from ancient living things	
Nuclear	Energy released from the nucleus of atoms	Nuclear energy heats water, producing steam, which spins a turbine and an alternator, generating electricity.

Table 1.3: Renewable energy sources

Energy source	Description	How electricity is generated
Solar	The Sun's energy	▪ The Sun directly heats water for use. ▪ Photons in the Sun's rays make electrons move in wires.
Wind	Kinetic energy in moving air particles in the atmosphere	Wind spins a turbine and an alternator.
Hydro	Gravitational potential energy in water stored up high and kinetic energy in moving water	▪ Moving water in a river spins a turbine and an alternator. ▪ Water high up in a dam flows downhill through pipes into a turbine that spins an alternator.
Wave and tidal	Kinetic energy in moving water in waves and tides	Moving water in the tides or waves flows through a device and spins a turbine and an alternator.
Geothermal	Heat energy from inside Earth's crust	Heat from inside Earth heats water to become steam, which spins a turbine and an alternator.
Biomass	▪ Chemical energy stored in organic material such as plants or microorganisms ▪ Contains energy from the Sun that is produced by plants through photosynthesis	▪ Biomass is burned to heat water, which becomes steam, which spins a turbine and an alternator. ▪ Biomass can also be converted into gas or liquid that can be used a fuel.

Electricity production is not always efficient

Generating electricity is usually inefficient. Some energy is always lost in the conversion to electricity. Hydro-electric plants are the most efficient source of electricity. Solar power is the least efficient, but advances in technology are expected to improve on its current efficiency of 18 per cent. Table 1.4 compares some common energy sources and their efficiencies. Scientists are constantly trying to improve energy production efficiency.

Table 1.4: The efficiency of energy sources

Energy source	Efficiency (approximate) (%)
Solar	18
Geothermal	20
Coal	29
Nuclear	33
Wind	35
Gas	38
Tidal	85
Hydro	90

Coal-fired power stations convert chemical energy into electrical energy

Coal has been one of the main power sources in Australia for a long time. In Figure 1.9, you can see how a coal-fired power station generates electricity.

- Coal is mined from the ground and transported to the power station.
- The coal is burned to produce heat, which is used to boil water.
- The boiling water produces steam, which is pushed under pressure through a turbine to make it spin.
- The spinning turbine is attached to an alternator that spins and produces electrical energy.
- The steam cools and forms liquid water again in cooling towers, and can be recycled through the plant.

Energy is lost at each step of the process, which is why it is not very efficient. Further energy is lost by transferring the electrical energy through power lines to homes.

The environmental impacts of coal power include habitat loss and damage to land through mining, pollution due to the greenhouse gases, particles, and other chemicals, such as sulfur dioxide, that cause acid rain.

There are fewer steps involved to produce solar energy from sunlight. However, solar panels are made of metals and silicon that come from mining, and their manufacture uses a lot of energy and produces waste products and pollution. Solar panels are also hard to recycle. All energy types have positives and negatives that we need to consider. You will learn more about this in Section 1.4.

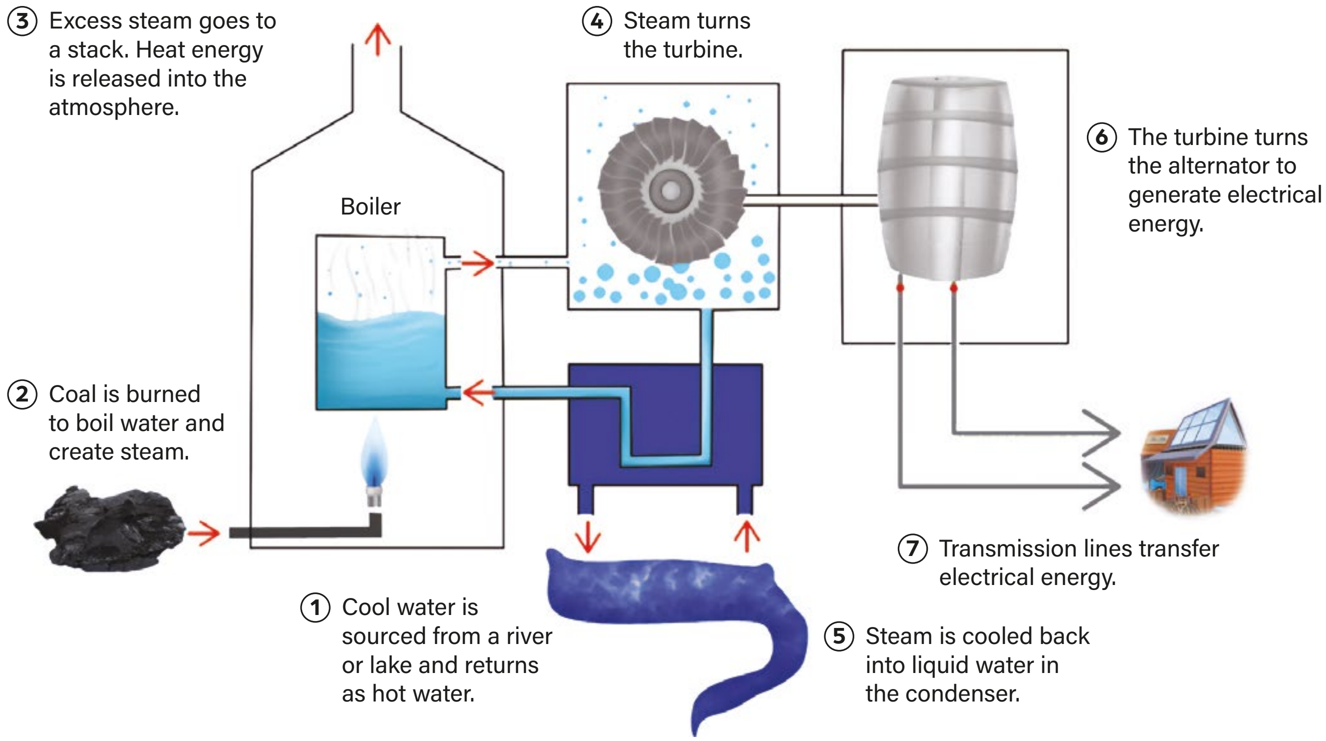


Figure 1.9: A coal-fired power plant only converts 29 per cent of the energy in coal into electricity; 71 per cent of the energy is wasted.

Learning Ladder

Energy

1. Identify and describe two energy sources.
2. Describe the difference between renewable and non-renewable energy sources.
3. Explain why nuclear energy is non-renewable.
4. Draw a flowchart to illustrate how coal is used to generate electricity. Label any energy transformations or transfers.
5. Use the efficiency data to evaluate the renewable energy sources listed in Table 1.4. Propose which one you think is the best option for future use.

Problem-solving

see page 425

1. Use the data in Table 1.4 to draw a graph in a format that makes it easy to visually compare the efficiency of different energy sources. More information about drawing graphs is available in the Science how-to section on pages 457–61.
2. Explain and compare the efficiency of solar and gas as energy sources.
3. Review your graph from Question 1 to compare and explain whether there is a pattern or difference between the efficiency of renewable and non-renewable energy sources.
4. Most energy sources are quite inefficient at generating electricity. Propose why we do not use more hydro or tidal electricity generation even though they have higher efficiencies.
5. Predict what will occur if society continues to use only fossil fuels as its main source of energy.

In context

Select one energy source and design a machine that can transform that energy source into electricity. Identify where the energy transformations and transfers occur, and any features that help improve efficiency.

Success criteria

- I can identify a number of renewable and non-renewable energy sources.
- I can describe how electrical energy can be generated from different energy sources.
- I can compare the efficiency of different energy sources and propose solutions to improve efficiency.

1·4 ▸ Electrical energy generation

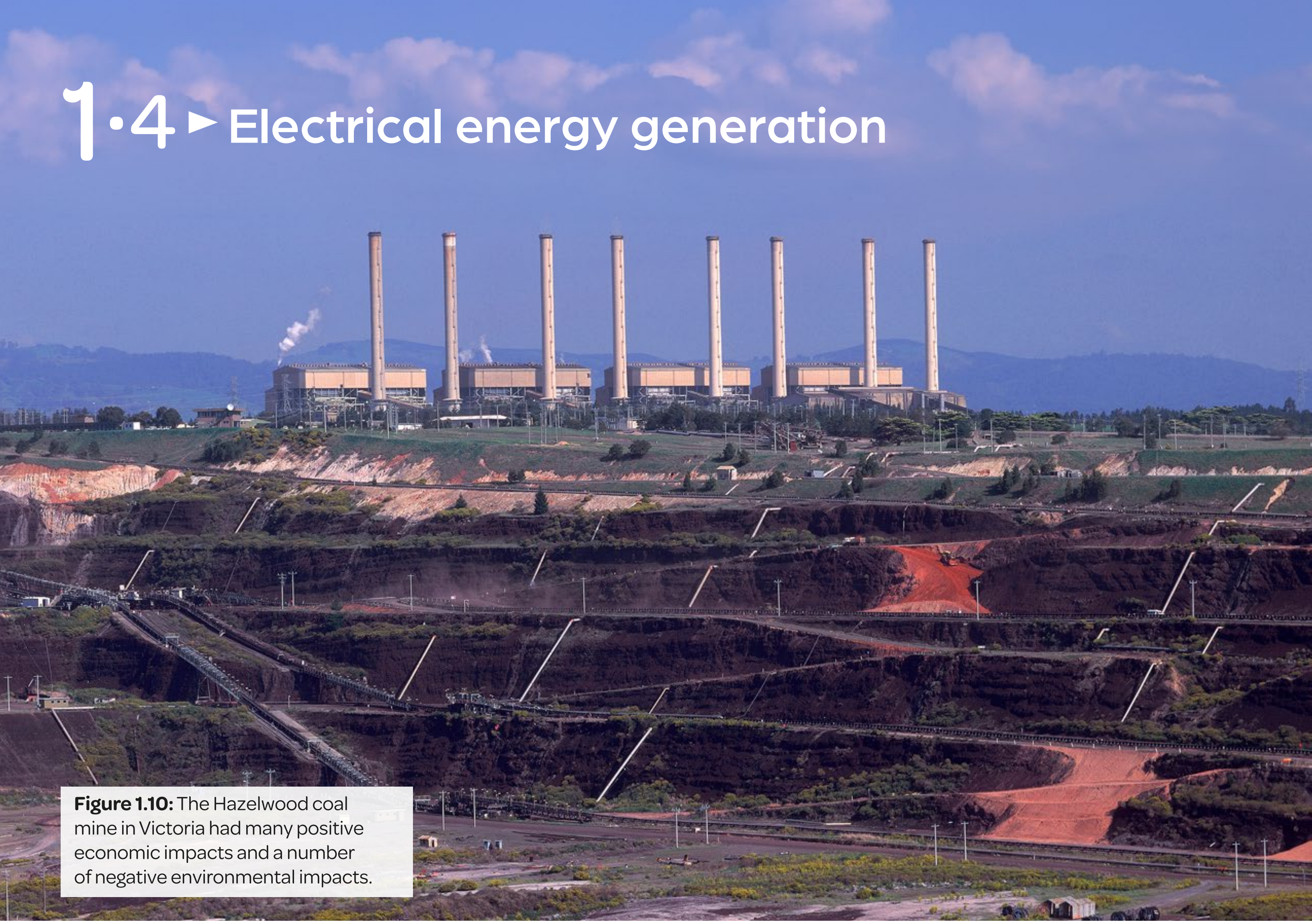


Figure 1.10: The Hazelwood coal mine in Victoria had many positive economic impacts and a number of negative environmental impacts.

Learning intention

At the end of this lesson, I will be able to evaluate the advantages and disadvantages of using renewable and non-renewable sources of energy to generate electricity.

Key terms

economy: the system of how a country makes and spends money and provides goods and services

greenhouse gas: a gas that traps the Sun's heat in Earth's atmosphere

pollution: a substance that enters the environment and has harmful or poisonous effects

Content group: Sources of energy

We use energy every day, and lots of it! When you turn on the television or the lights, do you think about where the energy you use comes from? Do you know what it costs, how it is generated, what technology is involved, and whether the energy you use is good or bad for the economy, our health or the environment? Producing energy is important for our future, and we must plan to reduce the impact of energy production and increase its efficiency, to reduce issues like global warming.

Energy sources have both advantages and disadvantages

Efficiency is only one consideration when selecting and planning for energy in future. There are also economic, technological and environmental considerations.

- Economic considerations are the costs associated with an energy source, such as how cheap it is to build, run and maintain a power plant and dispose of waste.

- Technological considerations include whether technology can make an energy source more efficient, reduce or store extra energy or dispose of wastes, making it safer or less polluting.
- Environmental considerations are how an energy source affects – positively or negatively – people and the environment.

Fossils fuels have been good for Australia but cause problems

The fossil fuel industry has been important for Australia's **economy**, building wealth. Fossil fuels have been readily available, which has made them relatively cheap. Approximately 85 per cent of all of Australia's electricity supply has usually come from coal and gas power. Our gas and coal industries have employed more than 200 000 people, and exporting coal and gas has contributed to Australia's economic wealth. This had made it hard for the country to move to more renewable energy sources, which might reduce economic growth. People who work in the coal and gas industries would need to find other jobs. However, switching to renewable energy could create new jobs.

When petrol, coal or gas is burned, dangerous chemicals are released into the environment. These can cause environmental problems such as acid rain, which can affect ecosystems, causing deaths of plants and animals. Acid rain is caused by pollutants such as sulfur dioxide and nitrogen oxides produced by burning fossil fuels. The pollutants enter the atmosphere where they dissolve in water to produce acid rain. Pollutants including particles and dust in the air can cause lung diseases and other medical conditions when breathed in or can enter water sources, causing further **pollution**.

Fossil fuels contribute to global warming

Carbon dioxide is a **greenhouse gas**. Greenhouse gases in the atmosphere trap additional heat energy from the Sun and warm the atmosphere. Trapping some heat is important for maintaining Earth's temperature so that it can support life. But trapping extra heat is known as the greenhouse effect and contributes to global warming and climate change. If Earth continues to heat up, the effects will vary with location. Our economy, lifestyle, health, disease and the environment will be affected.

- Sea levels will rise as polar ice melts, causing coastal areas to flood.
- Animals that live in frozen or alpine regions, such as penguins, polar bears and mountain pygmy possums, will lose their habitats and may become extinct.
- Crops we rely on for food will be more vulnerable to disease, reducing food production.
- There will be more extreme weather events such as heatwaves, hurricanes, droughts and floods.

Figure 1.11: Wind energy is a new industry that is creating new jobs and helping the economy.

Some energy sources may be better than others

Most energy sources have advantages as well as disadvantages, which need to be considered when assessing and selecting energy sources for the future (Table 1.5).

Table 1.5: Advantages and disadvantages of energy sources

Energy source	Advantages	Disadvantages
Gas	▪ Relatively cheap, readily available, current technology makes it easy to extract and use ▪ Lowest-polluting fossil fuel	▪ Finite fossil fuel; produces greenhouse gases and pollution ▪ Inefficient
Oil	▪ Relatively cheap, readily available, current technology makes it easy to extract and use	▪ Finite fossil fuel; produces greenhouse gases and high levels of pollution ▪ Inefficient ▪ High impact on environment when transport accidents occur
Coal	▪ Relatively cheap, readily available, constant supply of electricity, current technology makes it easy to extract and use	▪ Finite fossil fuel; produces greenhouse gases and high levels of pollution ▪ Inefficient ▪ Large mines impact on the landscape
Nuclear	▪ Small mining footprint and low impact on environment, low greenhouse gases ▪ Stable and constant source of electricity	▪ Very expensive; requires very large power plants ▪ Radioactive waste difficult to dispose of ▪ Higher risk of environmental contamination by radiation in an accident ▪ Non-renewable
Solar	▪ Renewable; freely available ▪ No greenhouse gas emissions ▪ Can be small local solar or large solar farms	▪ Requires mining for special and expensive finite metals ▪ Making panels is expensive ▪ Recycling solar panels is costly and not yet effective ▪ Only works when sunny
Wind	▪ Renewable; freely available ▪ No greenhouse gas emissions	▪ Requires large, expensive wind farms with expensive additional batteries ▪ Only works when windy ▪ Rotating blades cause vibrations that affect wildlife, including birds, and create noise for communities
Hydro	▪ Renewable; freely available ▪ No greenhouse gas emissions	▪ Only available at some locations ▪ Creating large dams affects the environment, flooding valleys
Wave and tidal	▪ Renewable; freely available ▪ No greenhouse gas emissions	▪ Only available in some locations ▪ Difficult and costly to build and maintain
Geothermal	▪ Renewable; cheap and readily available ▪ No greenhouse gas emissions.	▪ Only available in some locations ▪ Can be expensive and difficult to extract and use heat ▪ Pumping water into the ground can cause issues with land
Biomass	▪ Renewable ▪ Can be produced in most locations ▪ Often uses waste produced from other processes ▪ Produces greenhouse gases, but only the amount that would normally have been produced by rotting waste	▪ Must be constantly made or grown, and takes time and money to transport and create biomass fuel ▪ Rotting biomass can be a source of noxious smells and of disease

Figure 1.12: Although there are benefits to burning fossil fuels, pollution is a major problem.

Learning Ladder

Energy

1. Coal has been a major energy source in Australia. Identify one:
   - **a** economic advantage of using coal.
   - **b** technological advantage of using coal.
   - **c** environmental disadvantage of using coal.
2. Describe:
   - **a** the causes of global warming.
   - **b** the relationship between greenhouse gases and global warming.
   - **c** two possible effects of global warming on the environment.
   - **d** a possible impact of global warming on the economy.
3. Explain whether technology relating to energy generation can help reduce pollution or is the cause of pollution in the first place.
4. Select one energy source and discuss the advantages and disadvantages of continuing to use it. Include efficiency, economic, environmental and technological considerations.
5. Select what you think is the best energy source for the future. Provide reasons for why you think this.

Problem-solving

see page 425

1. Make a list of all the devices in your home that use energy. Select three devices and propose how you could alter them to reduce their energy use.
2. If you could only select two energy sources for the future to reduce global warming, what would they be? Explain the criteria you used to select these energy sources.
3. Suggest two ways that the impact of energy generation on global warming could be reduced.
4. Assess the effectiveness of one of your problem-solving strategies from Question 3.
5. Get a copy of an electricity bill that claims to be charging for 'green energy'.
   - **a** Conduct research into what 'green energy' means in regards to the bill.
   - **b** Identify the source of the 'green energy' being used to generate electricity.
   - **c** Evaluate whether the 'green energy' is really green.

In context

Iceland, Costa Rica and Uruguay get nearly 100 per cent of their energy from renewable sources. Undertake some research to identify the sources of energy in these countries. Could this be implemented in Australia?

Success criteria

- I can identify and evaluate the advantages and disadvantages of using renewable and non-renewable sources of energy to generate electricity.

1·5 ▸ Electric circuits

Learning intention

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

- identify the key features and components of an electric circuit
- draw simple circuit diagrams to represent circuit design.

Key terms

circuit: a closed path for transmitting electricity, including connecting wires and components connected to a power source

component: a device in a circuit that uses electrical energy

electron: a negatively charged particle in an atom

load: a component of a circuit that uses electrical energy

Content group: Electrical energy

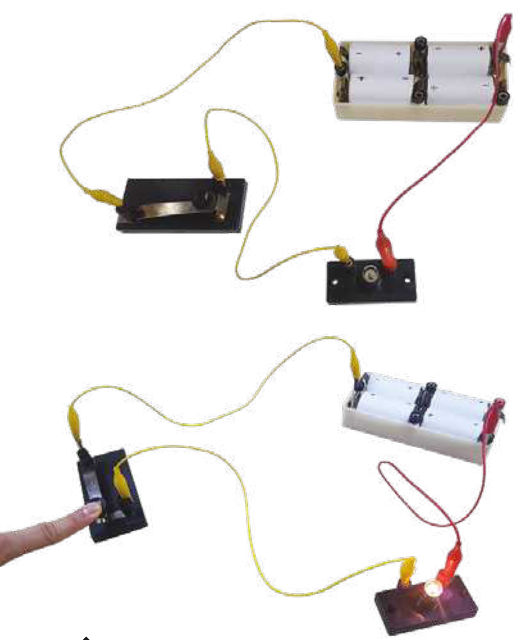


Figure 1.13: Turning on a switch changes an open circuit to a closed circuit.

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 transmitting 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 1.13). 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 converts that energy into another type. For example, a light bulb converts 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 1.14 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.

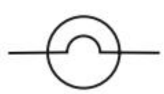
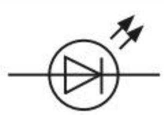
Circuit components are shown as standard symbols

Component symbols are nearly always shown in the same way. This means that anyone who knows these symbols can read a circuit diagram. Table 1.6 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 that the wires do not cross
5. check the circuit by tracing from the battery through each component and back to the battery.

Table 1.6: Common electrical components and their symbols. Look for other components throughout this focus area.

Component	Picture	Symbol
Open switch		
Closed switch		
Lamp/ light bulb		
LED (light-emitting diode)		
Cell		
Battery (multiple cells)		
Wire		

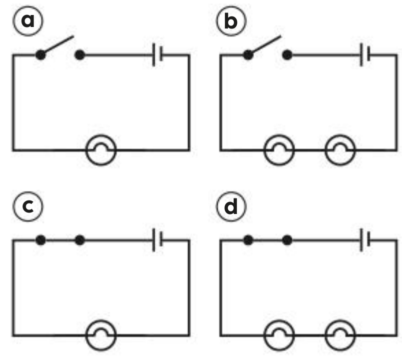


Figure 1.14: Circuit diagrams show the components of electric circuits in a simple and standardised way.

Learning Ladder

Energy

1. Identify the three main requirements when constructing a complete circuit. Explain why each is needed.
2. Describe what occurs when electrons flow around a closed circuit.
3. Explain the meaning of a load, providing an example.
4. Discuss the difference between a closed and an open circuit.
5. Evaluate the use of circuit diagrams in science to represent real circuits.

Observing *see page 398*

1. Accurately copy the symbols from Table 1.6.
2. In Figure 1.14, which circuits are open and which are closed? How do you know?
3. You observe that an LED in a circuit is not lighting up. What can you infer about the circuit that may be causing this?
4. Draw these components in a simple circuit: battery, open switch, LED. Ensure you follow the steps for drawing basic circuit diagrams.
5. Select the components required to make the circuit for a simple torch and draw it as a circuit diagram.

In context

Investigate different types of cells and batteries and their uses. Identify strengths and weaknesses for each type of cell or battery. Construct a table to present your results. Hint: Identify each selection as cell or battery.

Success criteria

- I can identify the features and components of an electric circuit.
- I can draw simple circuit diagrams to represent electric circuit design.

1·6 ▸ Energy in electric circuits

Learning intention

At the end of this lesson, I will be able to explain voltage, current and resistance in electric 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 1.6A

Modelling a simple circuit, page 475

Investigation 1.6B

Conductors and insulators, page 476

Content group: Electrical energy

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 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 1.15). 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.

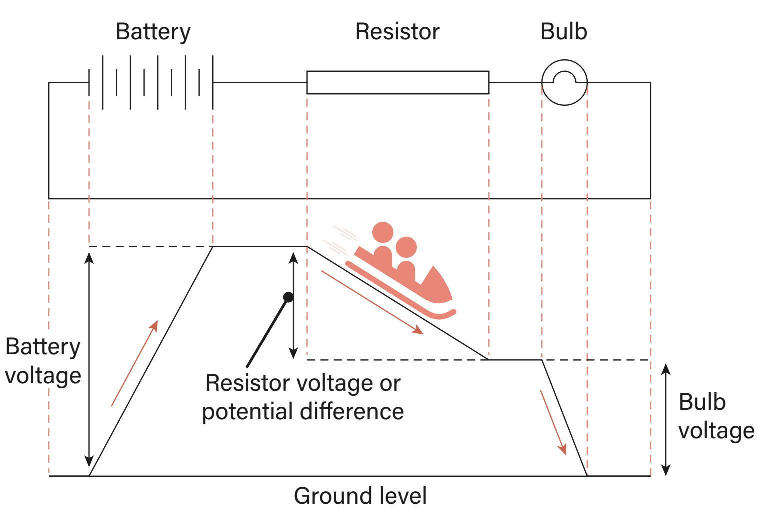


Figure 1.15: Voltage, or potential difference, is like the difference in height between two points on a rollercoaster.

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 1.16). 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 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.

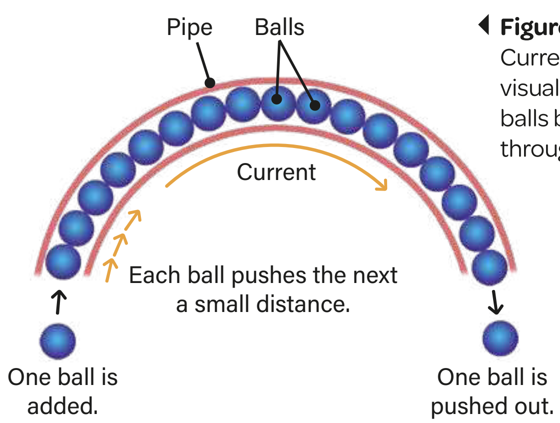


Figure 1.16: Current can be visualised as small balls being pushed through a pipe.

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.

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 1.17: The coloured bands on these resistors indicate the value of the resistance in ohms.

Learning Ladder

Energy

1. Identify these statements as true or false.
   - **a** Voltage is supplied by a resistor.
   - **b** Too much voltage will cause a bulb to fail.
   - **c** Current always flows clockwise.
   - **d** Current gets used up as it goes around a circuit.
   - **e** Resistance is measured in ohms.
   - **f** Conductors have zero resistance.
2. Describe the difference between voltage, current and resistance.
3. Distinguish between conductors and insulators and provide an example of each.
4. Discuss what happens to the voltage as electrons flow around a circuit.
5. Electrical tape is made of a flexible plastic with sticky adhesive on one side.
   - **a** What do you think electrical tape might be used for?
   - **b** Evaluate why plastic is a suitable material for electrical tape.

Observing

see page 398

1. Find out what device is used to measure voltage and what is used to measure current.
2. Construct a table to show the symbol and units for voltage, current and resistance. More information about constructing tables is available in the Science how-to section on pages 412–13.
3. In your home, identify a small lamp and a light on the ceiling. Observe the lights and identify which is brighter. What can you infer about the amount of voltage being used in each case?
4. A torch bulb states it is rated at 8 V. The bulb is inserted into a torch with a 12 V battery. Describe what will happen to the bulb.

In context

The units that voltage, current and resistance are measured in are all named after famous scientists. Conduct research into one of these scientists to explain their contribution to modern electricity.

Success criteria

- I can explain what is meant by voltage, current and resistance.
- I can describe how voltage, current and resistance behave in a circuit.

1.7 ▸ 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

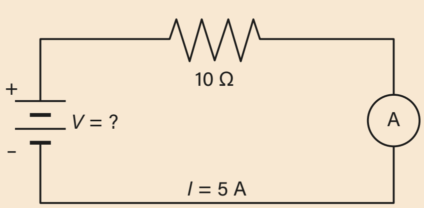
Ohm's law: a scientific law which demonstrates that the current through a conductor between two points is directly proportional to the voltage across the two points

voltmeter: a device that measures potential difference (voltage)

Investigation 1.7

Exploring Ohm's law, page 477

Content group: Electrical energy



Find the voltage (V):

Resistance = 10 Ω

Current = 5 A

Therefore:

$V = I \times R$

$= 5 \times 10$

$= 50$ V

Figure 1.18: An example of a calculation using Ohm's law to find the value of the voltage

German physicist Georg Ohm (1789–1854) discovered the relationship between voltage, current and resistance in an electric circuit. This relationship became known as **Ohm's law**.

Electrical current is proportional to voltage

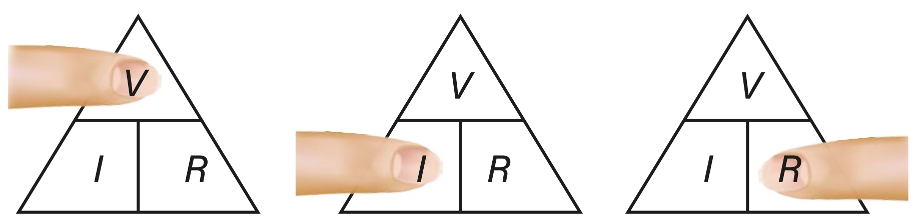
Ohm discovered that the relationship between current (I) in amps, voltage (V) in volts and resistance (R) in ohms can be summarised in the formula:

$$V = I \times R$$

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 1.19).

To find voltage: **To find current:** **To find resistance:**



$V = I \times R$ $I = \frac{V}{R}$ $R = \frac{V}{I}$

Figure 1.19: 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 1.20).

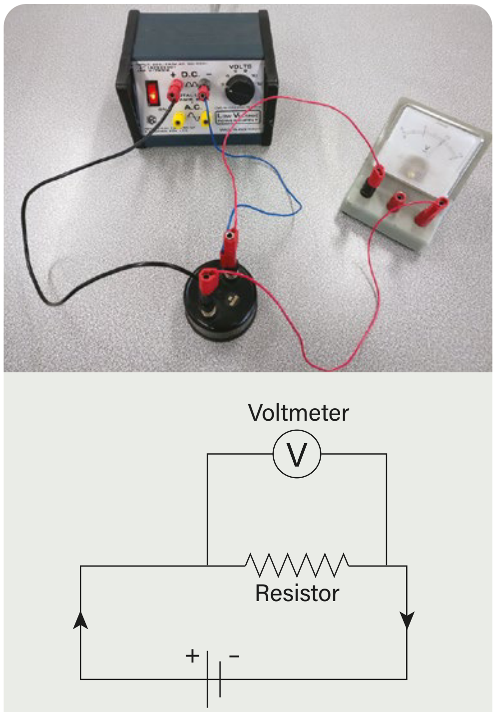
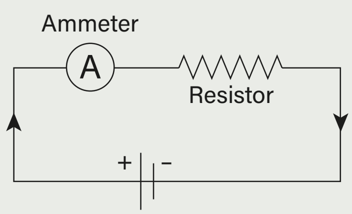


Figure 1.20: How to connect a voltmeter in parallel to take a measurement

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 1.21).

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.



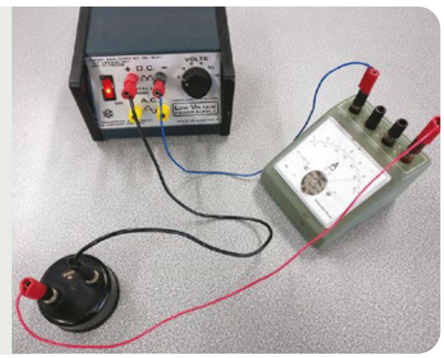


Figure 1.21: How to connect an ammeter in series to take a measurement

Learning Ladder

Energy

1. Use the Ohm's law triangle to identify the equations for measuring:
   a voltage **b** current **c** resistance.
2. Describe and compare conductors and insulators, using examples of each.
3. Explain Ohm's law in your own words.
4. Discuss the differences between an ohmic and a non-ohmic resistor.
5. Use Ohm's law to calculate the:
   a current if the voltage is 110 V and the resistance is 8 Ω.
   b voltage if the current is 8 A and the resistance is 2 Ω.

Conducting investigations

see page 408

1. In setting up a circuit to investigate Ohm's law, outline the safety considerations you would need to think about.
2. Identify the equipment you would need in order to build a basic circuit and measure the voltage and current.
3. **a** Discuss the difference in how you would connect an ammeter and a voltmeter in a circuit.
   b Describe how you would collect data about voltage and current and the unit used for each.
4. A student constructed the following results table in their Ohm's law investigation. Identify and explain the three errors in this data table.

Circuit	Voltage (*V*) Unit: volts (V)	Current (C) Unit: amperes (A)	Resistance (*R*) Unit: ohms (O)
1	10	2.5	
2	16	–4	
3	24	7	

5. Copy and complete the table above, making any corrections, and calculate the resistance in each circuit.

In context

Research a famous scientist (other than the one you researched in Section 1.6) to explain their contribution to modern electricity. Acknowledge your source with an appropriate reference (see the Science how-to section on page 443).

Success criteria

- I can explain the relationship between voltage, current and resistance, including conducting an experiment to demonstrate the relationship.
- I can calculate voltage, current and resistance using Ohm's law.

1.8 ▸ 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

reciprocal: the reciprocal of a number is 1 divided by that number

series circuit: a circuit in which components are connected in a line, so the current has only one path to take

Investigation 1.8

Series and parallel circuits, page 478

Content group: Electrical energy

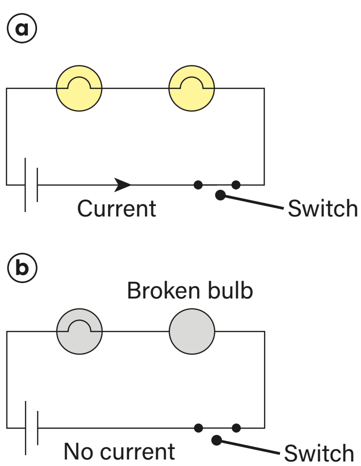


Figure 1.22: (a) In a complete series circuit, the bulbs light up. (b) A broken bulb results in an incomplete circuit and no bulbs light up.

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 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 1.22).

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 1.23).

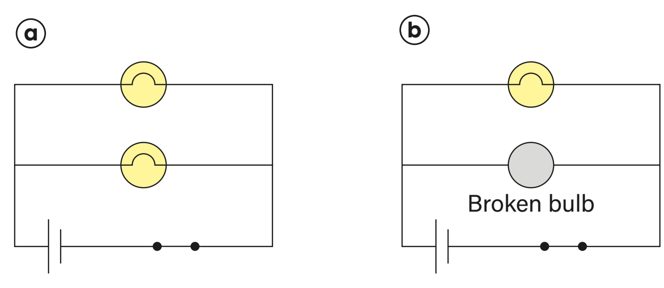
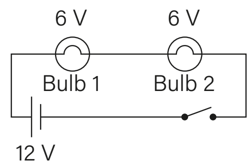
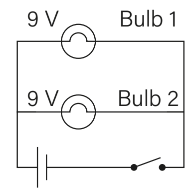
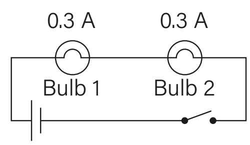
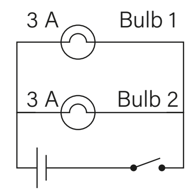
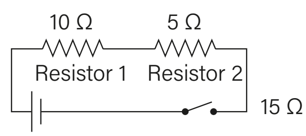
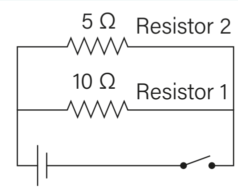


Figure 1.23: (a) In the complete parallel circuit, the bulbs light up. (b) A broken bulb does not result in an incomplete circuit and the other bulbs remain lit.

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 1.7: A summary of voltage, current and resistance in series and parallel circuits

	Series circuit	Parallel circuit
Voltage	The voltages across components add up to the total voltage supplied by the battery. 6 V + 6 V = 12 V Bulb 1 + bulb 2 = total 	The voltage across each component is the same. 9 V = 9 V = 9 V Bulb 1 = bulb 2 = total 
Current	The current is the same everywhere in the circuit. 0.3 A = 0.3 A = 0.3 A Bulb 1 = bulb 2 = total 	The current in each component adds up to the total current in the main branch containing the battery. 3 A + 3 A = 6 A Bulb 1 + bulb 2 = total 
Resistance	The resistances of components add up to the total resistance of the circuit. The total resistance in the circuit is more than the resistance of each component.  10 Ω + 5 Ω = 15 Ω Resistor 1 + resistor 2 = total	The total resistance is the **reciprocal** of the sum of the reciprocals of resistance of each component. The total resistance of the circuit is less than the resistance of each component.  $\frac{1}{10\ \Omega} + \frac{1}{5\ \Omega} = \frac{1}{\text{total}}$ $0.1\ \Omega + 0.2\ \Omega = \frac{1}{\text{total}}$ $0.3\ \Omega = \frac{1}{\text{total}}$ Total = 3.33 Ω

Learning Ladder

Energy

1. Draw simple labelled diagrams of a series circuit and a parallel circuit.
2. Describe the main differences between the placement of components in series and parallel circuits.
3. Using the concept of open and closed circuits, explain why all lights in a series circuit go out if one stops working.
4. Discuss and compare the difference in current between a series circuit and a parallel circuit.
5. Evaluate the differences in series and parallel circuits. Provide an example of a product that may contain a:
   - **a** series circuit
   - **b** parallel circuit.

Conducting investigations

see page 408

1. You set up a series circuit, but the lights do not work. You need to change the light bulbs. What safety precaution should you take first?
2. You have a parallel circuit with three globes on different branches, but you only have one ammeter. How will you measure the current in each branch?
3. A student constructs two circuits. In each circuit there are two 10 Ω resistors. One circuit is in series; the other is in parallel.
   - **a** Draw the two circuits, including where the voltmeter and ammeter would be connected.
   - **b** Calculate the resistance for each circuit.

In context

Design a circuit for a greeting card that, when opened, turns on a light and sets off a buzzer. The light and buzzer should operate independently but at the same time. If possible, set up your circuit and test it in class.

Success criteria

- I can explain and compare the structure of series and parallel circuits.
- I can explain the differences in voltage, current and resistance in series and parallel circuits.

1.9 ▸ Electrical appliance efficiency

Learning intention

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

- explain star ratings for appliances
- 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 1.9

Comparing energy in appliances, page 480

Content group: Electrical energy

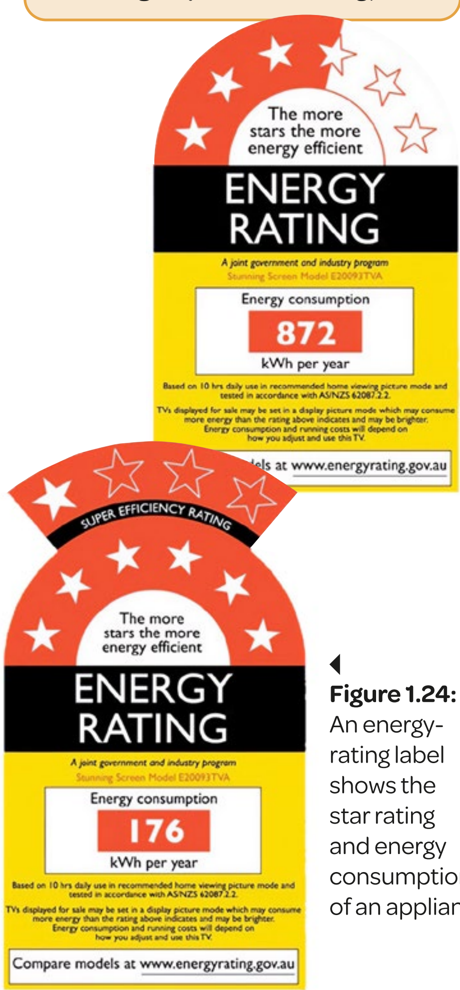


Figure 1.24: An energy-rating label shows the star rating and energy consumption of an appliance.

Energy–efficient appliances are cheaper to run and 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 out 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 even pool pumps! These star ratings help us 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:

$$\text{Annual running cost} = \underset{\text{(kWh)}}{\text{total energy consumption}} \times \underset{\text{(dollars per kWh)}}{\text{electricity tariff}}$$

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).

Similar appliances use different amounts of energy

In Figure 1.24 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 1.8 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?

Table 1.8: 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

Figure 1.25: Appliances in stores must display energy-rating labels.

Learning Ladder

Energy

1. a List these bulbs from most to least efficient: compact fluorescent, incandescent, LED, halogen.
   b Which of the bulb types in part a would you expect to get the hottest as it runs? Explain your answer.
   c Propose a reason why the government started phasing out inefficient light bulbs.
2. Explain two reasons why society is moving towards energy-efficient devices.
3. Discuss the criteria used to evaluate the efficiency of an electrical appliance.
4. Evaluate the importance of government regulation to help create change in people's purchasing behaviour.

Problem-solving

see page 425

1. Propose how a star rating can help solve environmental problems related to energy use.
2. Explain the link between using low-star appliances and the amount of emissions that may be produced in energy production from fossil fuels.
3. If you were designing an energy rating for cars, what criteria would you use to assess the efficiency?
4. Create a table (like Table 1.8) to compare the following clothes dryers and assess which appliance you would purchase. Assume an energy tariff of $0.42. More information about constructing tables is available in the Science how-to section on pages 412–13.
   - Clothes dryer 1: star rating 6, energy consumption 130 kWh.
   - Clothes dryer 2: star rating 7, energy consumption 138 kWh.
5. Review your response to Question 4 and critically evaluate your answer, taking into account the following features. Justify whether you have changed your mind.
   - Clothes dryer 1: Has a sensor to turn off automatically when clothes are dry; fits 8.5 kg of clothes.
   - Clothes dryer 2: Does not turn off automatically when clothes are dry; fits 7.5 kg of clothes.

In context

Find 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 discuss energy-rating labels for appliances and compare the efficiency of appliances.
- I can compare energy transformed over time in appliances.

1·10 ▸ Optimising energy use

Learning intention

At the end of this lesson, I will be able to describe and evaluate ways to optimise current energy use.

Key terms

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 us of something

thermal: heat

Investigation 1.10

Insulation and heat transfer, page 482

Content group: Global future energy needs

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 all houses. To ensure there is enough energy, we need to optimise its use by maximising energy efficiency while reducing energy waste.

Energy sources should be renewable and 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.

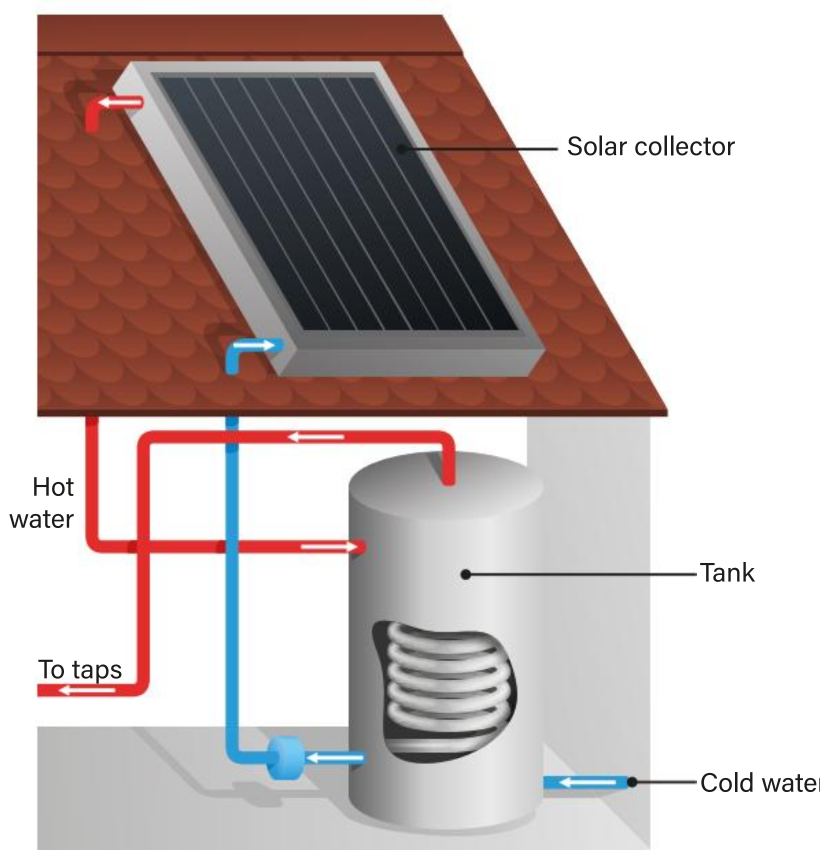


Figure 1.26: In a solar hot water system, rooftop solar panels produce hot water for households.

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.

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 or air conditioner a little
- 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 1.27).

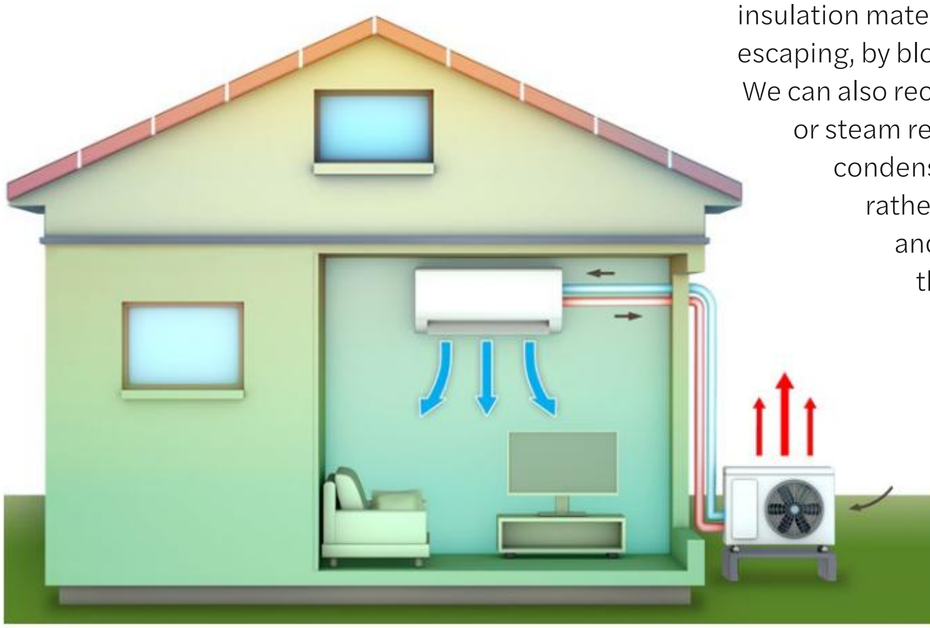
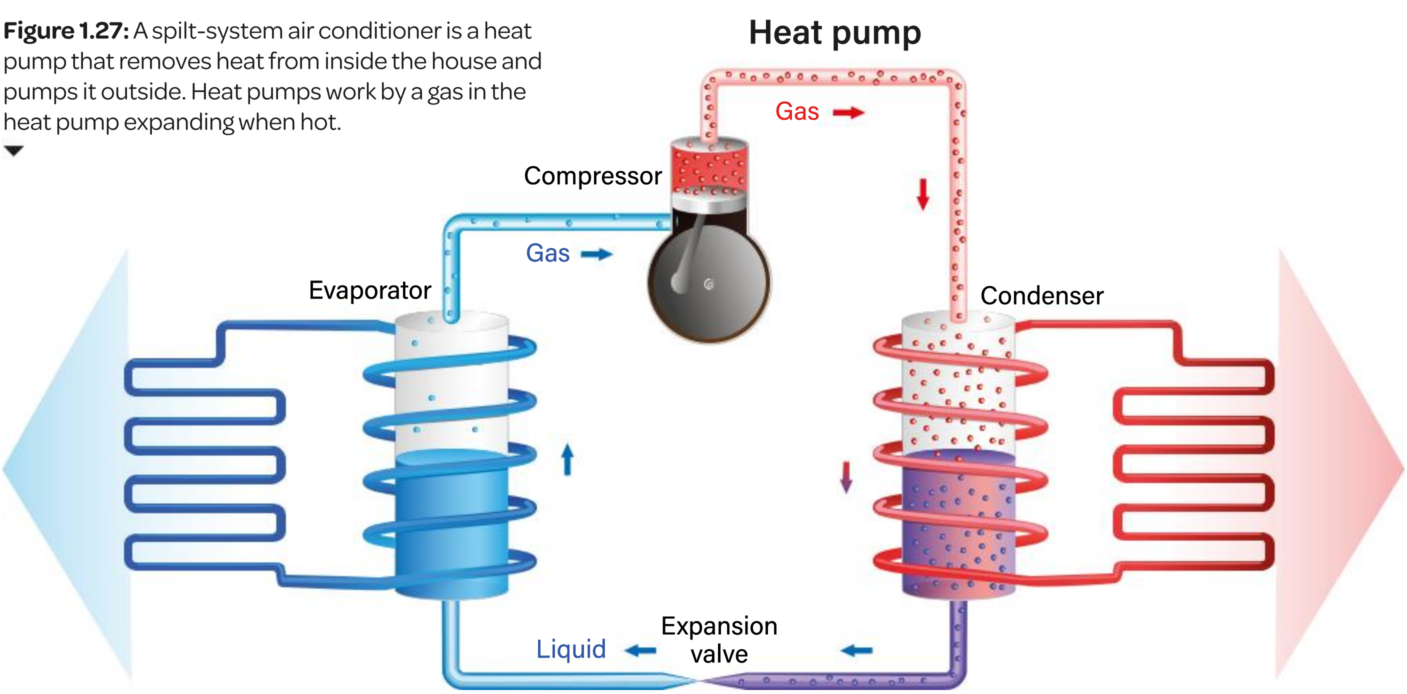


Figure 1.27: A spilt-system air conditioner is a heat pump that removes heat from inside the house and pumps it outside. Heat pumps work by a gas in the heat pump expanding when hot.



Building materials can help control temperatures

Insulation acts as a barrier to heat flow. 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 7, 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 types of insulation: bulk and reflective. Bulk insulation relies on air trapped in 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.

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 1.28).

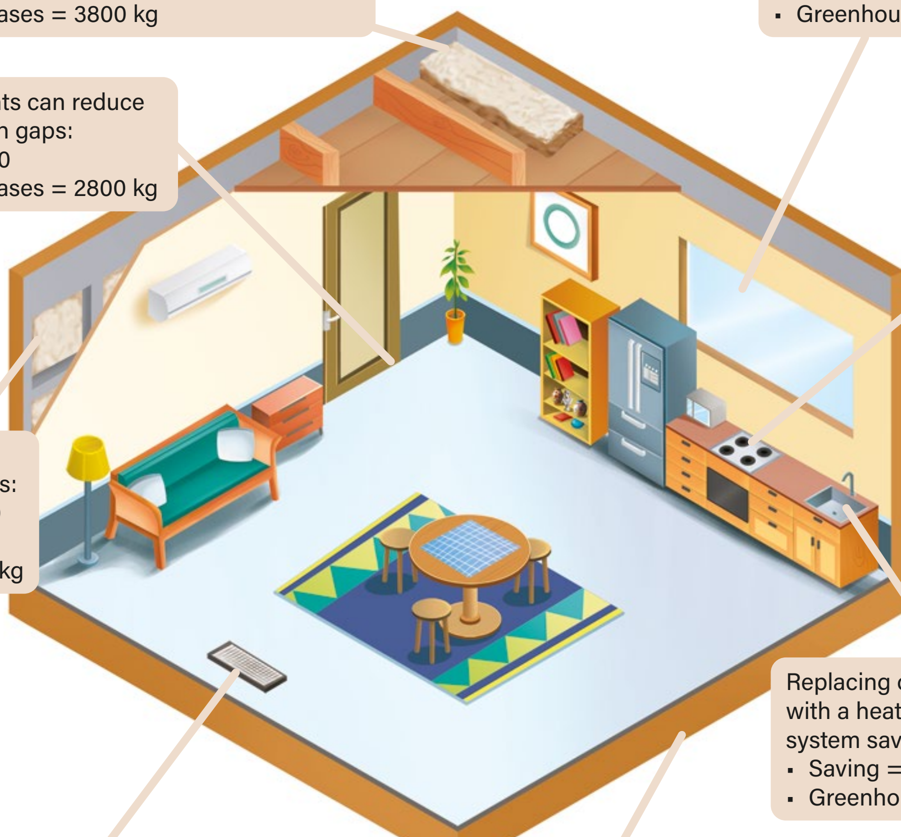
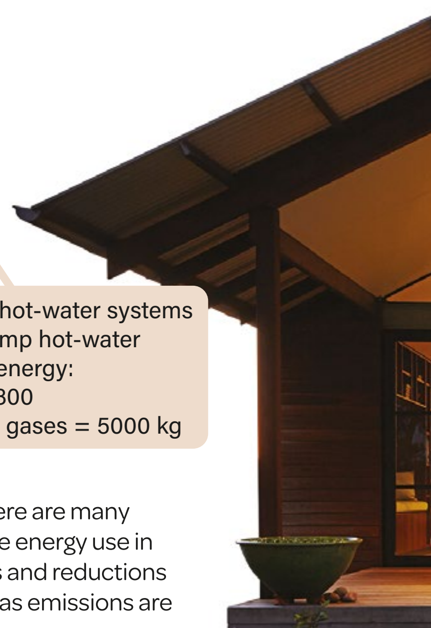


Figure 1.28: There are many ways to optimise energy use in a home. Savings and reductions in greenhouse gas emissions are estimates shown over one year.



Passive design helps regulate a building's temperature

Passive design is building design that considers the climate, where a building will be located and many design features to keep it at a comfortable temperature without using appliances for heating or cooling (Figure 1.29). 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 1.29:** This Australian house uses passive design, such as the design of its roof, to help control the temperature inside.

Learning Ladder

Energy

1. Identify three ways to optimise energy use.
2. Describe two ways to design a home to make it more sustainable and efficient.
3. Study Figure 1.27 and explain how a heat pump works in relation to energy transfer.
4. Discuss and give an example of why using more solar energy can be a good idea.
5. Evaluate whether gas or electricity is a better option for energy in the future, using examples from this section.

Problem-solving

see page 425

1. Propose how you could reduce energy loss from a dog kennel to help keep a dog warm.
2. Explain how finding ways to optimise energy use can help solve our energy problems.
3. **a** Collate the data from Figure 1.28 about financial savings and greenhouse gas emission reductions per year into a table. More information about constructing tables is available in the Science how-to section on pages 412–13.

   b Using the criteria of financial savings and greenhouse gas emission reductions, identify the two best energy optimising changes you could make to a house. Explain why you selected these options.
4. If you were designing a new house, what strategies could you use to ensure it was energy efficient?
5. Based on the data you collated in Question 3, evaluate whether it is worth spending money to improve the energy efficiency of a home.

In context

Conduct research into the cost of installing a new heat pump hot-water system or solar electricity system. Find out the financial savings that may be gained by this investment and calculate how many years it would take to get your investment back so that you can start saving money.

Success criteria

- I can describe ways to optimise current energy use.
- I can evaluate the use of current and alternative energy choices.

1·11 ▸ Global future energy needs

Learning intention

At the end of this lesson, I will be able to identify past trends and predict future trends in energy use, and link this to reasons for developing alternative energy sources in future.

Key terms

by-product: an unwanted or waste product of a process

smog: a form of air pollution

sustainable: able to be maintained at a certain rate or level

temperature inversion: when a layer of hot air in the atmosphere stops circulation of air away from Earth's surface

Investigation 1.11

Atmospheric convection and inversion layer, page 484

Content group: Global future energy needs

Figure 1.30: Mining companies must rehabilitate the mined land once the mine is closed. The land may have different uses in the future, but it must be made safe and free of pollution.

Since the Industrial Revolution, our energy use has soared. Energy use has had very positive impacts, but it has also had negative impacts on the environment, including contributing to global warming. We need to understand our energy use so as to improve it and reduce its impact.

Global energy use is increasing

Figure 1.31 shows how energy use has soared over the past 200 years. It is clear that energy use has increased in line with the global population growth. The types of energy use have also changed. Biofuel and coal were the main energy types between 1820 and 1920. From about 1940, new energy types grew very quickly as technology developed and the population started to increase at a faster rate.

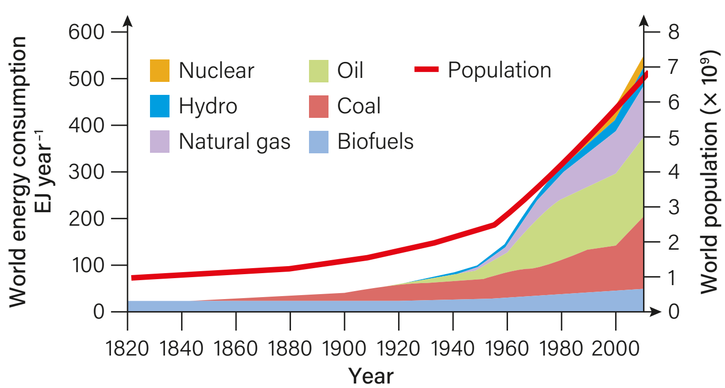


Figure 1.31: Historical global energy use by energy type and population growth (1 EJ = 1 exajoule = 10^{18} joules)

Australia is following energy trends

Energy use in Australia has grown substantially as the population has grown. Figure 1.32 shows our energy production since 1977. Australia mostly uses fossil fuels for energy production. Coal accounted for about 61 per cent of Australia's energy production in 2021–22, followed by natural gas at 32 per cent. Australia is currently using a lot of fossil fuels to supply energy for transport, households and industry. Renewables are a small but growing part of our energy supply.

We should develop alternative energy sources

We need to invest in new and alternative energy sources, for a number of reasons. Well-developed, alternative energy sources can ensure that:

- energy is used efficiently, thereby reducing the environmental impacts of waste energy and waste **by-products** on plant and animal life, water, soil and the atmosphere
- humans can live comfortably and enjoy our way of life, including balancing our use of energy, technology and the environment to ensure a more **sustainable** future.

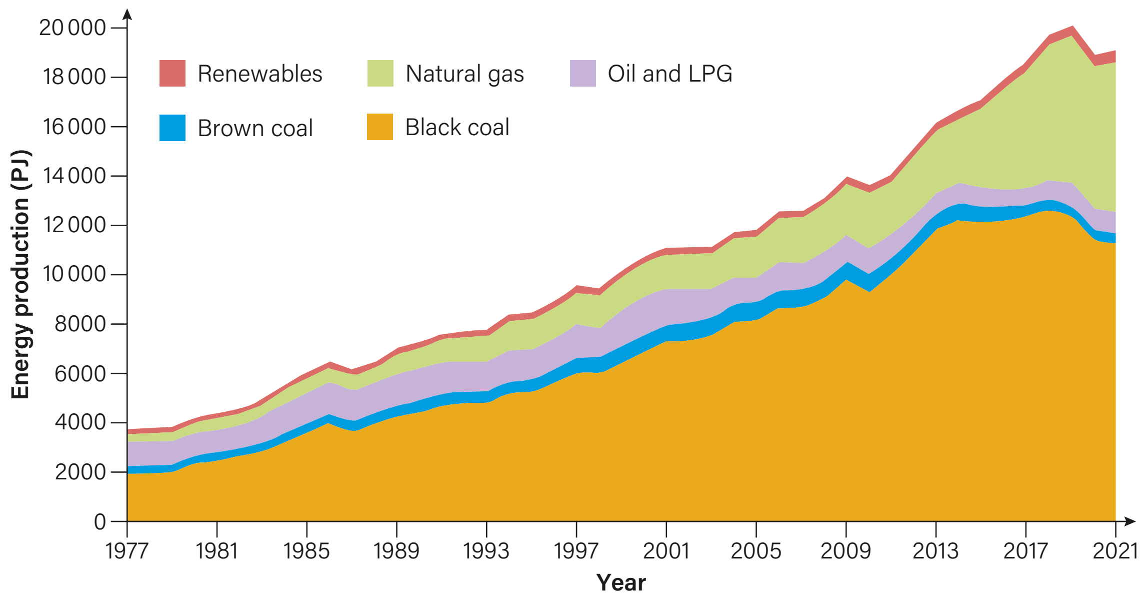


Figure 1.32: Energy use in Australia is similar to that of the rest of the word and is projected to grow. (1 PJ = 1 petajoule = 10^{15} joules)

Energy production and use affects the environment

Increased energy production and use affects the environment in many ways. We have already discussed how fossil fuels contribute to global warming, but each type of energy affects the environment in some way.

Mining

Mining is required to extract fossil fuels and uranium to make them available for energy production. For solar energy and battery storage, precious metals are required to be mined in order to make electronic components. Mining produces waste materials that may be toxic, and affects the land directly. After mining, rehabilitation is often required.

Precious metals such as lithium, nickel, cobalt, gold or manganese required for batteries and electrical components are also limited or finite in supply. Unless we can recycle them more efficiently, eventually the cost of energy and its potential impacts will increase further.

Loss of environment

Mining can directly affect the environment. The digging of open-cut coal mines removes large amounts of land. Hydro power requires dams that flood valleys and destroy wildlife habitats.

Burning fossil fuels also produces acidic gases that enter the atmosphere and dissolve in water to form acid rain. Acid rain damages plants and has destroyed forests and crops in some parts of the world.

Visual impact and noise

Wind farms also have impacts on the landscape. Large-scale wind farms are visible from far away, whether they are on land or the ocean. Wind farms also pose dangers to bird life and can be noisy.

Other activities related to energy production, such as mining, dams or large solar farms, also have a visual impact.

Climate change

An important environmental impact of energy production is climate change, caused by global warming. Global warming is the heating of the atmosphere caused by increased greenhouse gases that trap heat in Earth’s atmosphere, raising global temperatures. The environmental effects of increased temperatures include rising sea levels, changing weather patterns such as more intense storms, floods and droughts, and other events.

Changing weather patterns and increasing levels of gases and pollutants in the atmosphere also affect the health of people, animals and plants. For example, climate change will affect both the amount and quality of food that can be produced, and this directly affects our health.

Air quality

Under normal conditions, the Sun’s energy heats the ground, which then heats the air just above it. The warmer air rises as cooler air sinks below it. In this way, fresh air can circulate.

During a **temperature inversion**, the layer of air close to the ground is cooler than the air above it, which prevents fresh air from circulating. The warm air is sometimes a result of pollutants from car exhausts, factories and burning of fossil fuels to make electricity, which can produce **smog**. Temperature inversions can be worse in valleys, where air circulation is further prevented by the surrounding hills.

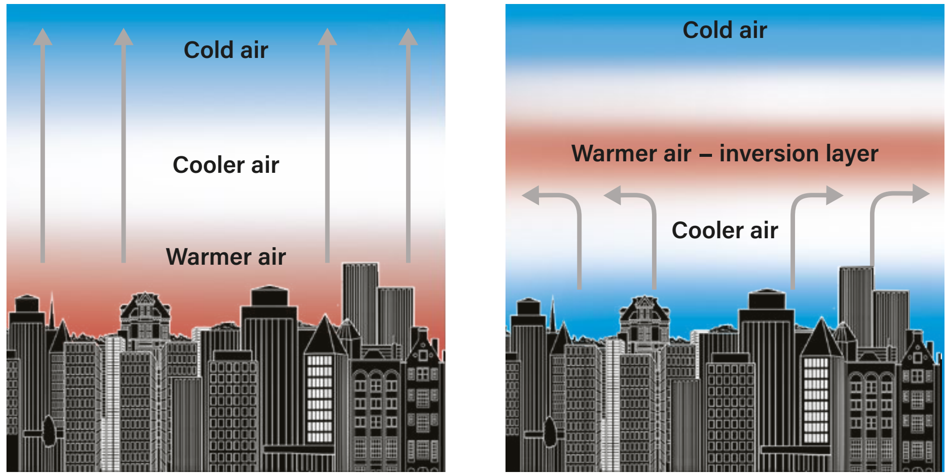


Figure 1.33: Under normal conditions (left), air is able to circulate. In a temperature inversion (right), warm air traps cooler air, preventing circulation.

Smog contains a variety of dangerous chemicals, including ozone, which is a molecule made up of three oxygen atoms. Increased smog levels can cause problems such as breathing difficulties and lung damage, coughing and throat irritation, asthma symptoms and irritated eyes. Children, elderly people and those with respiratory conditions are at most risk of health problems from smog.

Renewable energy sources make less heat

The electrical energy we use is generated in a variety of ways. It can be made from both non-renewable and renewable energy resources. Non-renewable energy resources such as coal, oil and natural gas are burned to release heat energy. In this process, water is heated to produce steam that turns turbines. This heat energy is transformed into electrical energy. As we have learnt, these energy sources have low efficiency, meaning a lot of heat is wasted and escapes into the atmosphere.

Renewable energy sources such as wind power, hydro-electricity and solar power convert energy into electricity more directly, and produce much less waste heat in the process. For example, wind and hydro energy sources directly turn turbines to generate electrical energy, and inefficient heating of water is not needed.

This means that renewable energy can be a better option in future, as it can reduce some of the environmental impacts outlined above.

Australia's mix of energy generation is changing

In response to the problems caused by energy production, including waste heat and other environmental impacts, there is a lot of debate about how we should produce and use energy in future. Australia is using more renewable energy and investing in new energy sources and supply and storage systems.

As in other countries, the use of renewable electricity in Australia is increasing. Figure 1.34 shows that Australia has increased the use of solar and wind energy sources since about 2010.

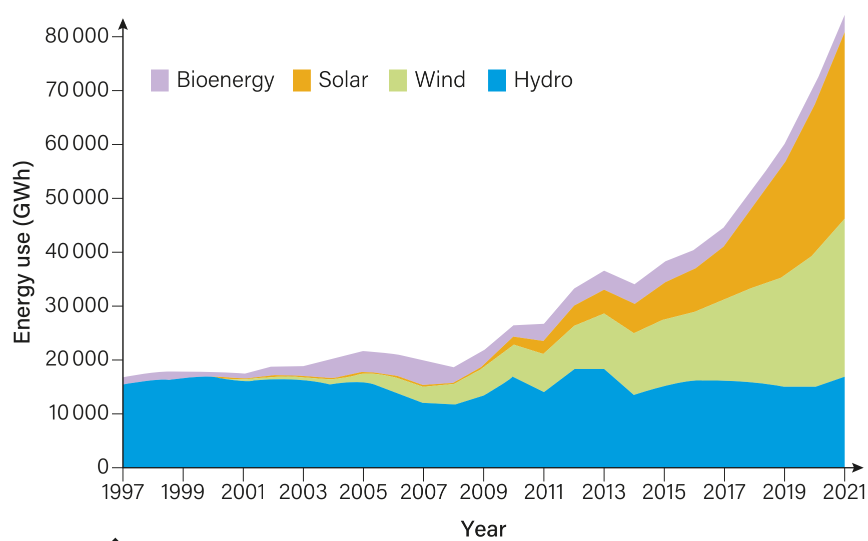


Figure 1.34: Renewable electricity sources in Australia (1 GWh = 1 gigawatt-hour)

The fuel mix used to produce electricity is different in each state, because each state has had access to different fuels and sources of energy in the past.

Figure 1.35 shows that coal continues to be the main source of electricity in New South Wales, Victoria and Queensland, making up more than 58 per cent of generation in all three states in 2022. But the use of coal is decreasing, having dropped below 50 per cent of total Australian generation for the first time in 2021–22.

Renewables accounted for 98 per cent of generation in Tasmania, due to a high use of hydro power. Renewables were 71 per cent of electricity supply in South Australia.

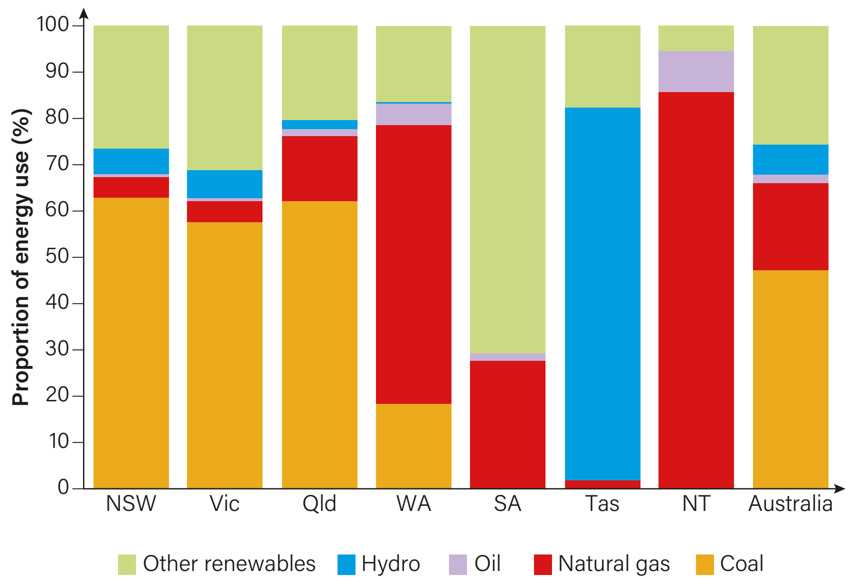


Figure 1.35: Each state of Australia uses a different mix of fuel types to produce electricity.

Learning Ladder

Energy

1 **a** Identify two ways that using fossil fuels can affect the environment.

b Identify two ways that alternative or renewable energy can have a positive impact on the environment.

2 Describe a sustainable energy practice and compare it to a non-sustainable energy practice.

3 Explain why the increasing use of energy and population growth are following similar patterns.

4 **a** Discuss the use of energy historically, compared to today, including what has changed in society over time and why that may have happened.

b Based on the historical use of energy in society, discuss the future use of energy, including:

- whether energy use will increase, stabilise or decrease
- what may happen to the mixture and types of energy sources used
- the reasons for your proposed energy trends in future.

5 **a** Compare the energy use of each Australian state, using Figure 1.35, and propose why some states have a much higher use of renewable energy than others.

b Evaluate reasons for the future use of current and alternative energy options across all the states.

Problem-solving

see page 425

1 Suggest ways to reduce the impact of continuing to use fossil fuels until it can be reduced.

2 Explain the relationship between the burning of fossil fuels and climate change.

3 Develop a set of criteria you could use for selecting future alternative energy sources.

4 Imagine you have been asked to propose ways to reduce the impact of new wind farms on the community and environment. Develop and assess a problem-solving process with at least six key steps you can take. When thinking about your process and steps, consider what you need to know or find out, who you would need to talk to, and how you would use that information to propose a solution to your problem.

5 According to Figure 1.34, the use of hydro-electricity in Australia has always been relatively high and remained stable. Evaluate why the use of hydro has not increased further as Australia has invested in renewables, when other renewable energy sources are increasing.

In context

Find out more about and summarise the energy strategy in your state. What is your state trying to do, or to invest in, to ensure a sustainable energy supply in future? Present your findings in any way you like.

Success criteria

- I can describe past and future trends in energy use at a global, national and state level.
- I can explain reasons for developing alternative energy sources.

1.12 ▸ Energy in context

> **Learning intention**
>
> At the end of this lesson, I will be able to evaluate the development of alternative energy sources to meet and reduce global energy demand.
>
> **Key terms**
>
> **fuel cell:** a device that converts hydrogen and oxygen into electricity
>
> **hybrid:** a combination of two or more things
>
> **life-cycle analysis:** a way to consider the impact of a device from its creation, while in use and when disposed of
>
> **vehicle:** a car, bus or truck
>
> **Content group:** Energy in context

Passenger cars in Australia use 40 per cent more fuel than cars in the European Union, 20 per cent more than cars in the United States and 15 per cent more than cars in New Zealand. This difference is because Australians have preferred cars with larger engines and fewer diesel-powered engines. But there is a transition underway in Australia to more efficient cars to reduce energy demand, greenhouse gas emissions and pollution.

More efficient cars reduce energy demand

There are many alternative energy sources for **vehicles**, or cars, that will allow us to reduce energy demand. Petrol and diesel internal combustion engines have been the main engines in Australia, but there are now many options.

- Internal combustion engines burn fuel in the engine in controlled explosions inside cylinders that push pistons. This makes the engine spin and energy is transferred to the wheels.
- Battery electric vehicles use electricity in batteries to drive electric motors that are directly attached to the wheels.
- **Hybrid** electric vehicles use both a combustion engine and batteries to power the car. Batteries in hybrid electric vehicles recharge as you drive.
- Plug-in hybrid electric vehicles use both a combustion engine and batteries to power the car but must be recharged by plugging in. They have larger batteries than hybrids, so they can go further on batteries alone.
- Hydrogen cell vehicles are powered by a **fuel cell** that converts hydrogen into electricity that drives electric motors.

Table 1.9 summarises some of these energy technologies.

Figure 1.36: Australia has had a dependence on cars for transportation, including a preference for larger cars.

Table 1.9: Comparison of car engine technologies

Vehicle type		Source of energy	Motor type	Emissions	Efficiency (%)
Internal combustion engine	Petrol	Fossil fuel	Engine	High	20–30
	Diesel	Fossil fuel	Engine	High	30–50
	Hydrogen	Water or fossil fuel	Engine	Zero	20–30
Electric vehicle	Battery electric vehicle	Electricity	Electric motor	Zero	70–90
	Hybrid electric vehicle	Fossil fuel/ electricity	Engine/electric motor	Medium–high	25–40
	Plug-in hybrid electric vehicle	Fossil fuel/ electricity	Engine/electric motor	Medium	30–50
	Hydrogen fuel cell	Water or fossil fuel	Electric motor	Zero	40–50

Some cars are more efficient than others

When it comes to energy loss, cars are really good at it! Table 1.9 shows the efficiency of different vehicles. Energy is lost from cars in many ways – internal combustion engines produce a lot of heat that is wasted energy from the fuel that is burned, meaning they are one of the most inefficient types of cars.

Hybrid electric vehicles are more efficient than internal combustion vehicles, especially in stop-and-go driving, because the regenerative braking recycles waste energy from the brakes to charge the batteries. But the efficiency of a hybrid car is still only 25–40 per cent. Figure 1.37 shows where energy is wasted from a hybrid car.

A fully electric vehicle is the most efficient, at 70–90 per cent. Because energy goes directly from the battery to the motors that are attached to the wheels, there are fewer ways energy can be wasted through friction or heat. Even though they may be cleaner, both types of hydrogen engine are quite inefficient.

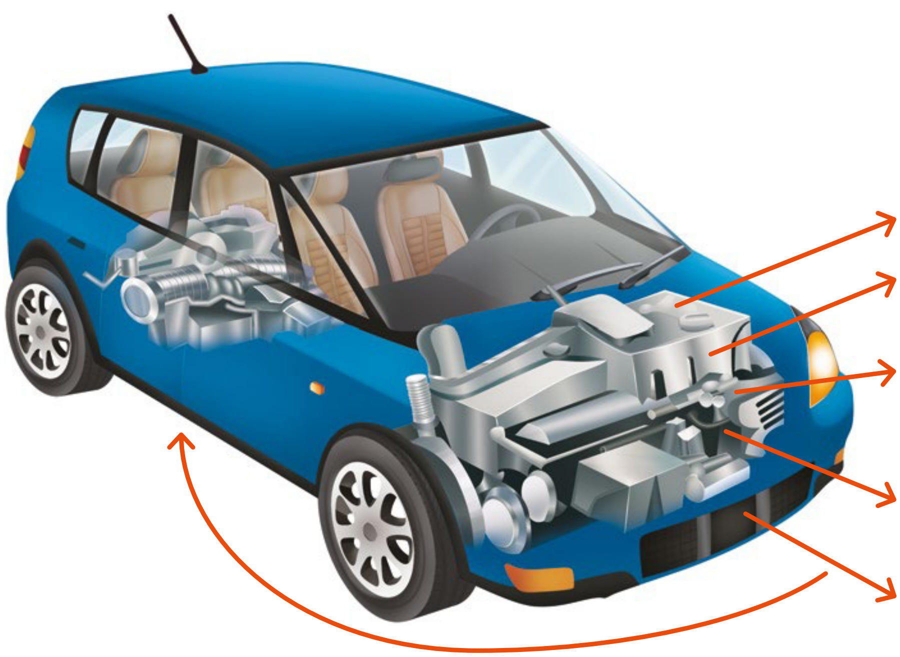


Figure 1.37: Energy is lost and recovered in a hybrid car in many ways.

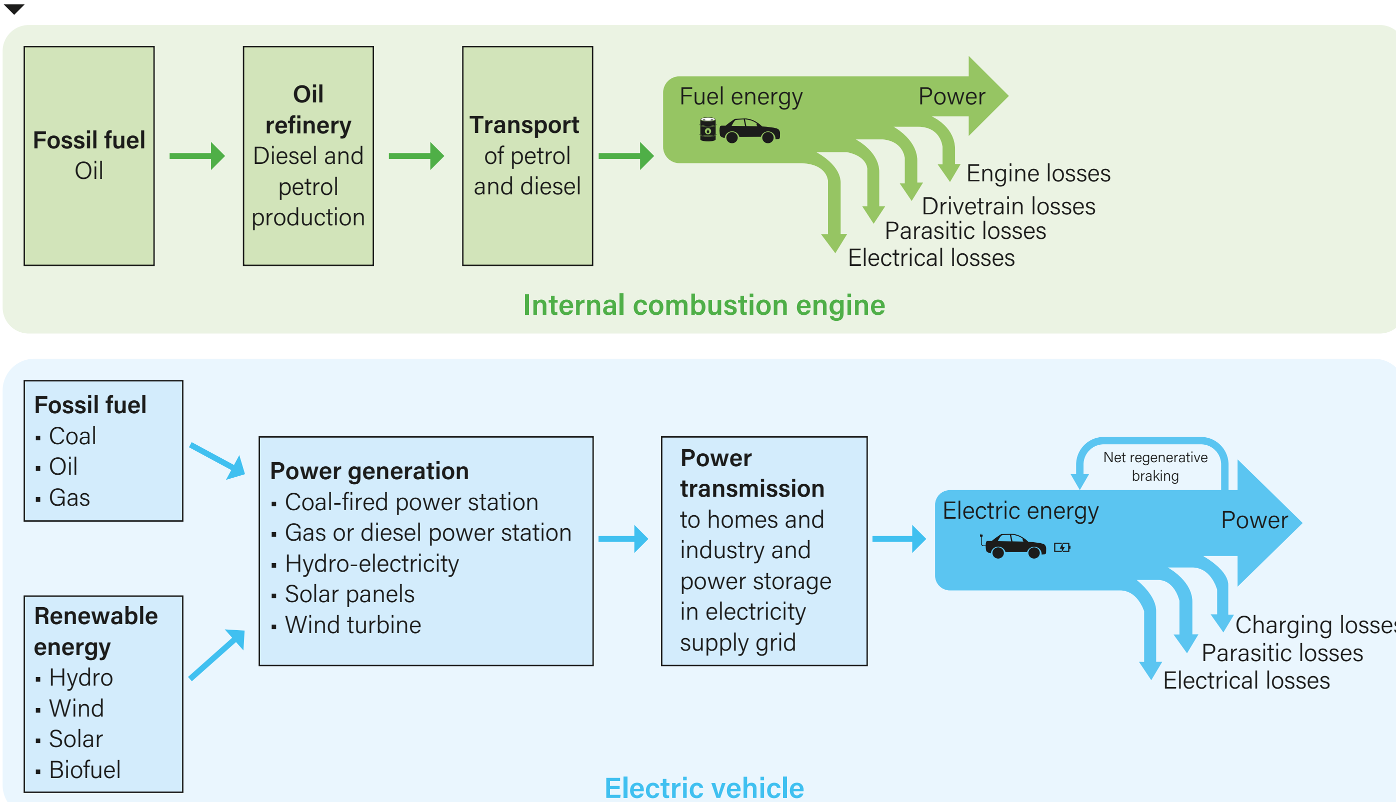
Life-cycle analysis helps us evaluate impact

When it comes to reducing global energy consumption and improving environmental impacts from vehicles, we can do a **life-cycle analysis**. A life-cycle analysis considers everything from the manufacturing of the car and its use until disposal, in order to assess its energy use and emissions over its lifetime.

For example, Table 1.9 shows that a battery electric vehicle seems to produce zero emissions. But if the electricity that is used to charge the batteries comes from fossil fuels, then the emissions and pollution can still be high. Other impacts may come from activities such as mining to produce the precious metals needed to make batteries. And during the manufacturing of the car itself, many materials are used that require energy and produce both waste energy and other by-products, including pollutants.

Figure 1.38 compares electric vehicles and combustion engine vehicles to show the stages of the life cycle where energy is produced, used and lost, and where pollution and emissions may be produced.

Figure 1.38: A life-cycle comparison of energy in electric and internal combustion engine cars



Hydrogen may be a clean fuel

Hydrogen may be a better fuel because the only product of burning hydrogen to make energy is water. There are no pollutants.

Hydrogen + oxygen → water

As shown in Table 1.9, there are two types of hydrogen engine and both work by turning hydrogen into water in different ways. A hydrogen combustion engine burns the hydrogen by igniting it just like a petrol engine. A fuel cell is more efficient because it produces electricity in a controlled chemical reaction between hydrogen and oxygen, so less energy is lost as heat.

But where does the hydrogen come from? Hydrogen is made by one of two methods:

- using large amounts of electricity to split water into hydrogen and oxygen
- from other chemicals such as methane gas (a fossil fuel).

Both of these methods require energy and can produce pollution or by-products. So, although a hydrogen engine produces zero emissions, the process for producing and using hydrogen is not always clean or efficient.

Figure 1.39: A hydrogen fuel cell for a truck engine

Learning Ladder

Energy

1. Identify the energy source for :
   - **a** an internal combustion engine.
   - **b** a plug-in hybrid vehicle.
   - **c** a fuel cell.
2. Describe what a life-cycle analysis is, and explain how it may help develop more sustainable vehicles.
3. Explain why a battery electric vehicle is more efficient than a hybrid electric vehicle, when both run on batteries.
4. Discuss the difference in energy transformation that occurs in a hydrogen internal combustion engine and a hydrogen fuel cell.
5. Evaluate the seven types of vehicles in Table 1.9 and rank them in order from best to worst. Explain the criteria you have used to rank them.

Problem-solving

see page 425

1. In Figure 1.37, only 25–40 per cent of the energy is transferred to the wheels. Suggest where the rest of this energy goes.
2. Explain, with examples, how cars contribute to environmental problems.
3. You want to purchase a car that has low emissions, high efficiency and minimal environmental impact. Which vehicle would you select from Table 1.9 and why?
4. Construct a strategy for a life-cycle analysis of a car. Use Figure 1.38 to help you think about each stage of the life cycle. Write down the information you would need to collect and what you will do with it.
5. Some scientists claim that hydrogen is a clean fuel and should be the main fuel in future. Evaluate this claim and state whether you agree.

Success criteria

- I can use examples to evaluate the development of alternative energy sources to meet and reduce global energy demand.

► Energy summary

Law of conservation of energy

- Energy is the ability to do work.
- The law of conservation of energy states that energy can never be created or destroyed; it can only change into different forms.
- Some types of energy include:

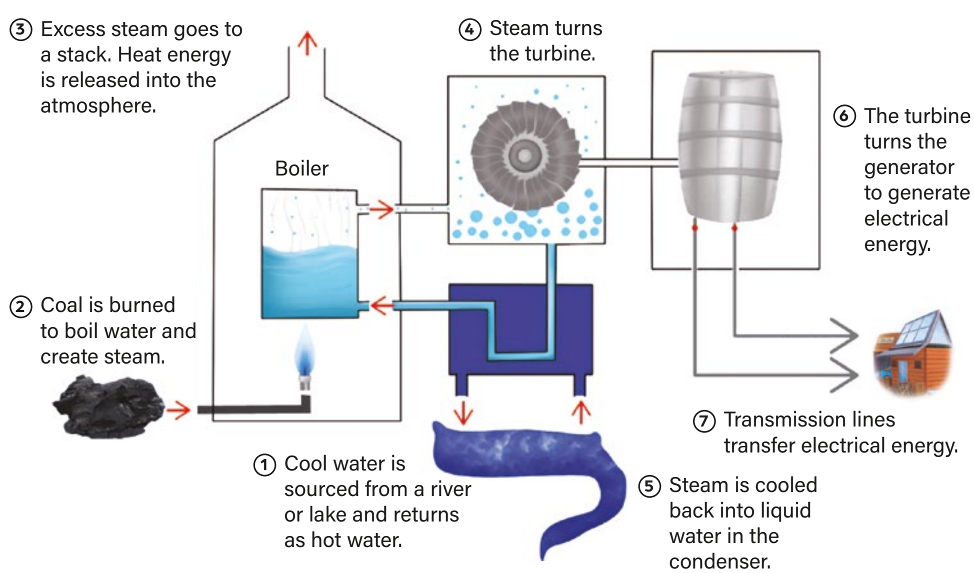
Chemical energy: energy stored in chemical bonds.
Elastic potential energy: energy stored in an object that has been stretched or compressed.
Electrical energy: energy that travels through electrical circuits.
Gravitational potential energy: stored in an object raised to a higher point.
Heat energy: energy in the form of vibrating particles in solids, liquids and gases.
Kinetic energy: energy of objects in motion.
Light energy: energy in the form of waves, emitted from a glowing object.
Nuclear energy: energy stored in or released from the nuclei of atoms.
Sound energy: energy in the form of vibrating particles and transferred as waves.

- Energy can be transferred from one object or one place to another.
- Energy can be transformed from one type of energy to another.

- Energy is lost in energy transfers and transformations. For example, rubber balls bounce higher than tennis balls, because they lose less energy in the form of heat and sound through friction with the air and the ground.
- All devices waste or lose energy.
  - Moving objects lose energy as heat and sound because of friction.
  - Most electrical devices lose energy as heat and sound.
  - Most machines lose energy as heat and sound.
- Energy efficiency is how much usable energy is produced compared to how much energy has been supplied. Less energy waste = more efficient energy use.
- The unit of energy is the joule (J).

Sources of energy

- Most energy sources can be used to generate electrical energy. The energy source is usually used to spin a turbine.



Sources of energy CONTINUED

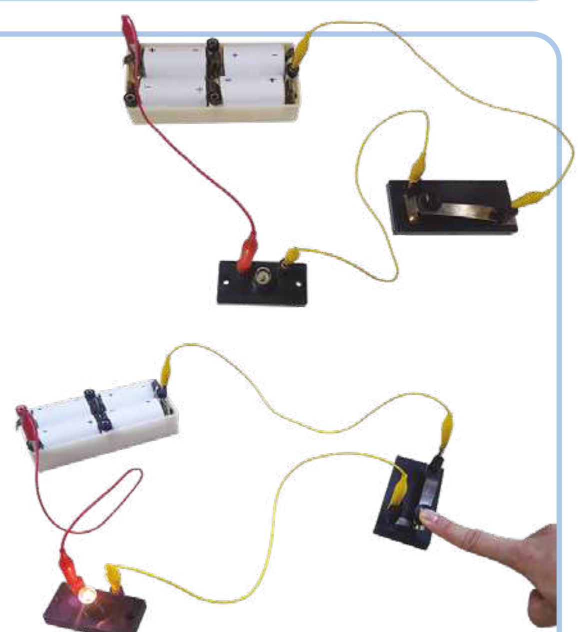
- Some sources of energy will run out and cannot be replaced – they are *non-renewable*.
- *Renewable* energy sources will not run out.
- Most of Australia's electricity has been generated (produced) by burning fossil fuels. Fossil fuels such as coal, oil and gas take millions of years to form.
- The process of producing energy is usually not very efficient, with a lot of energy lost during production as heat, light, sound and friction. More energy is lost when transferring the electricity to our houses.

Renewable energy	Efficiency (%)
Solar	18
Geothermal	20
Wind	35
Tidal	85
Hydro	90
Non-renewable energy	**Efficiency (%)**
Coal	29
Nuclear	33
Gas	38

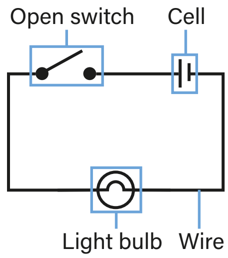
- Energy sources should be considered in regard to:
  - **Economic considerations**: the costs associated with making, using and disposing of an energy source.
  - **Technological considerations**: whether technology can make an energy source more efficient, reduce or store extra energy or dispose of wastes, making it safer or less polluting.
  - **Environmental considerations**: how an energy source affects – positively or negatively – people and the environment.
- Although there are economic and social benefits to burning fossil fuels, pollution and global warming is a major problem.
- Carbon dioxide is a greenhouse gas released when fossil fuels are burned. Greenhouse gases in the atmosphere trap additional heat energy from the Sun and warm the atmosphere, causing global warming.

Electrical energy

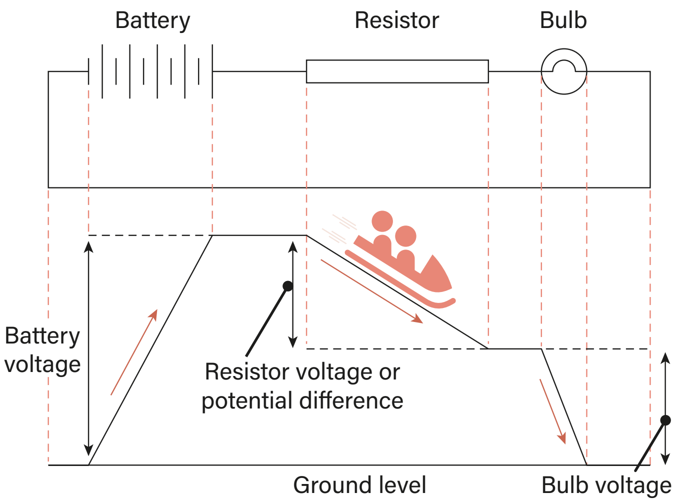
- An electric circuit is a closed path for transmitting electricity or electrical energy. A circuit consists of:
  - an energy source, such as a battery or generator
  - components that transform electrical energy into other forms of energy, such as a light bulb or motor
  - wires that connect the components to the power source and each other, to make a complete path back to the energy source.
- 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 that uses electrical energy.
  - As electrons pass through a load, they transfer their energy to the component, which converts that energy into another type.



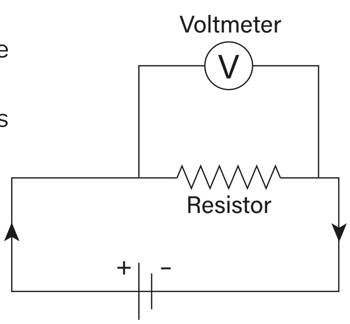
- Electric circuits can be drawn as diagrams. Each component has a symbol.
- Voltage is a measure of electric potential energy. When we measure voltage, we measure the potential difference, which is the difference in potential energy between two points in the circuit.



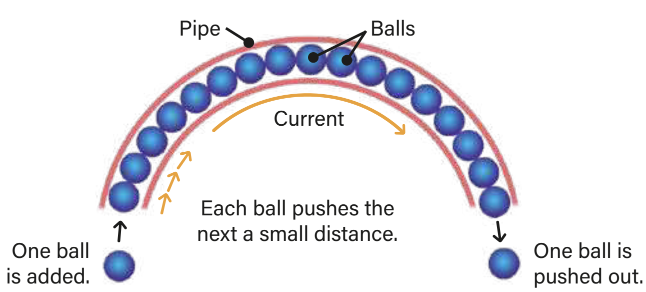
- Voltage has the symbol *V* and its unit is the volt (symbol V).



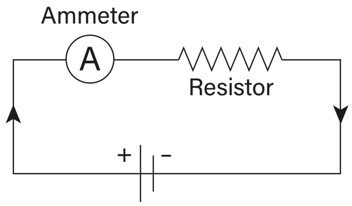
- A voltmeter measures the potential difference, or voltage, across two points in a circuit.



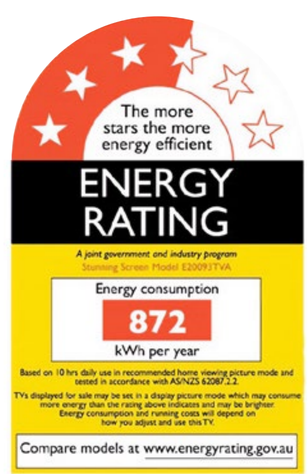
- Current is a measure of the rate of flow of charged particles (electrons) in a circuit. It can be visualised as small balls being pushed through a pipe.
- Current has the symbol *I* and its unit is the ampere (or amp) (symbol A).



- An ammeter measures current. It is connected as a part of the circuit so that the current goes through it.

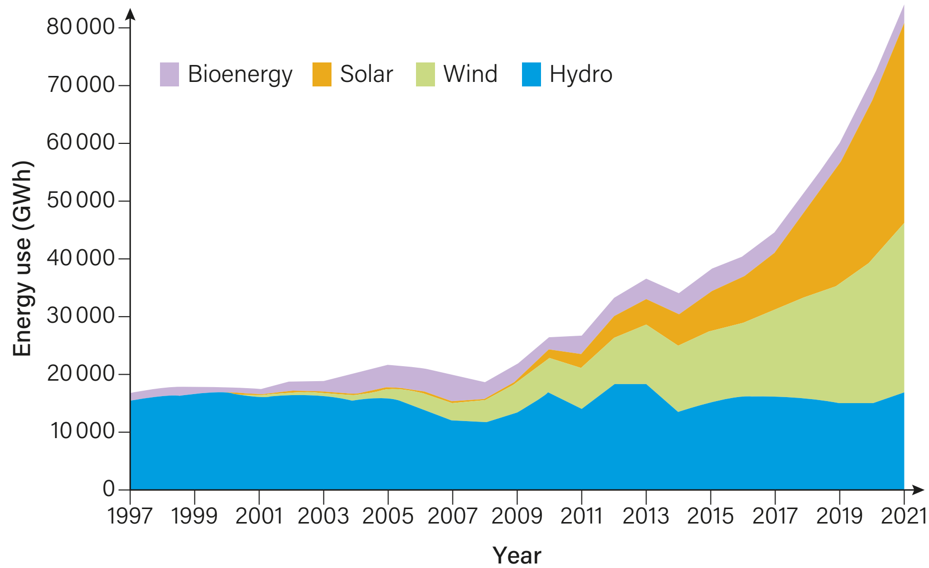


- Some materials, including most metals, such as copper, allow charge to flow more easily and are known as conductors.
- Other materials, such as rubber, resist the flow of charge and are called insulators.
- Resistance of a substance has the symbol *R* and its unit is the ohm (symbol Ω). A component with resistance converts electrical energy into other forms of energy, such as heat.
- Ohm's law is the relationship between current (*I*) in amps, voltage (*V*) in volts and resistance (*R*) in ohms, and is summarised in the formula: $V = I \times R$.
- Components in a *series circuit* are arranged one after another. There is only one path for the current to flow through. A broken bulb in a series will result in an incomplete circuit and no bulbs will light up.
- In a *parallel circuit*, each component is on a different branch of the circuit. A broken bulb does not result in an incomplete circuit and the other bulbs remain lit.
- 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.
  - 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 one hour.
  - Annual running cost = total energy consumption (kWh) × electricity tariff (dollars per kWh).



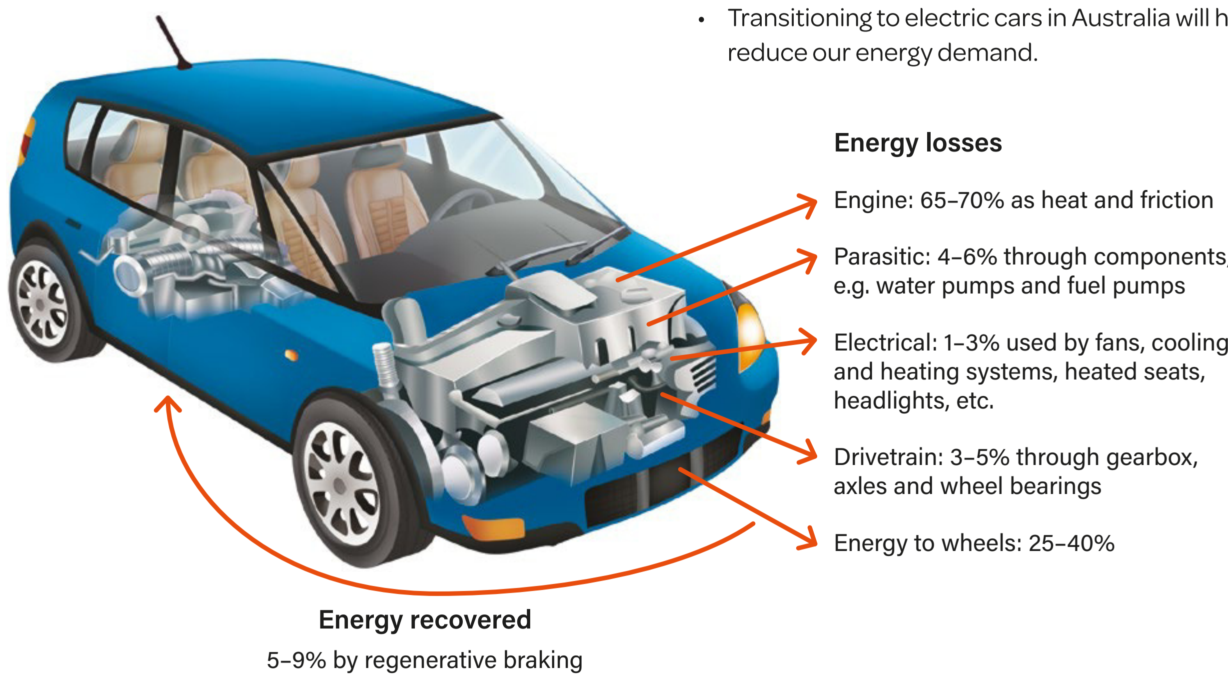
Global future energy needs

- We need to maximise energy efficiency and reduce energy waste by using renewable energy and efficient appliances (e.g. heat pumps), and by turning off appliances when not in use.
- Insulation reduces heat waste.
- Light colours reflect more heat.
- Passive design is energy efficient and helps to regulate a building's temperature.
- Reducing energy use and waste reduces pollution and energy bills. Selecting more efficient engines for cars reduces energy use.
- Energy use globally is increasing with population. Australia's mix of energy generation is changing to be more renewable.



Energy in context

- It is important that we are able to transition to sustainable energy sources, to reduce future demand.
- Hybrid vehicles are more efficient than petrol cars, and fully electric cars are more efficient than hybrids and reduce emissions.
- Transitioning to electric cars in Australia will help to reduce our energy demand.



Masterclass

Steps in progression

		1	2
Content	Energy	Identify whether biomass is a renewable or non-renewable energy source.	Describe how biomass can be used to create a sustainable energy practice. Give examples to justify your answer.
Processes	Observing	Identify some scientific tools scientists could use to investigate the production or use of biofuels.	Select one of these tools from step 1 and identify the observations and measurements that could be made with that tool.
	Conducting investigations	To determine how much energy a biofuel contains, scientists burn a sample inside a calorimeter. Outline some safety precautions you would need to take when using a calorimeter.	Use a diagram to describe how a calorimeter works, and outline what it measures.
	Problem-solving	Propose a solution to one of the potential problems of using biomass to create energy.	Explain the biomass cycle and outline the effect this may have on carbon dioxide in the atmosphere.

Biomass energy production and use in Australia

Biomass energy, or 'bioenergy', is energy generated from the conversion of biomass into heat, electricity, biogas, and liquid fuels such as biodiesel and ethanol. Biomass is organic matter from living things and comes from forestry, farming and household green waste. Basically, the energy from biomass is converted to a useful form of energy using techniques such as fermentation, gasification or combustion (burning). The energy in biomass comes from the Sun, via the energy produced by plants through photosynthesis. The efficiency of biomass energy production can depend upon the method used to make it.

Biomass can reduce carbon dioxide emissions, as shown in Figure 1.40. It can also be used to produce other useful products, including renewable bitumen (for making roads) and biomass-based concrete. Using biomass can also reduce the amount of rubbish that goes into landfill. Australia produces only about

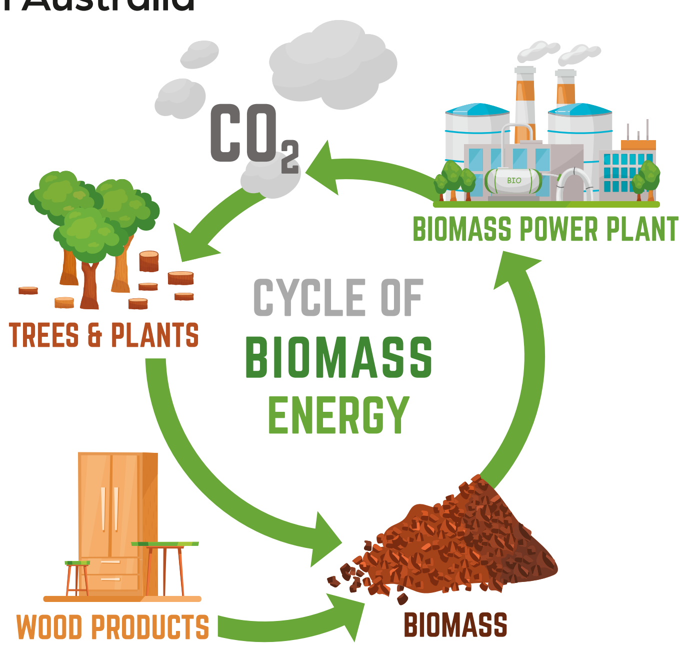


Figure 1.40: The biomass cycle can recycle carbon in the atmosphere, helping to reduce overall emissions.

Demonstrate your understanding

3	4	5	
Explain why it is important, when exploring new bioenergy projects, to consider the efficiency of the process used to produce energy.	Use Figure 1.40 to discuss how methods for producing biomass could be improved to ensure optimal energy outputs while reducing negative impacts.	Evaluate the use of bioenergy as a fuel for the future and propose whether Australia should expand its use of bioenergy.	
Propose one inference that you can make after reading the text about biofuels.	Outline some observations you would need to make to answer the following question: Are biofuels a better energy source than fossil fuels?	Based on your observations identified in step 4, identify scientific equipment you may need to use to make these observations accurately.	Science how-to p. 398
Construct a table for collecting results to compare two types of biofuels when using a calorimeter.	Research some actual calorimeter results for testing the energy in biodiesel. Record these results in a table and write a statement describing what the results show.	Conduct research to identify data that compares the efficiency of different types of biofuels. Be sure to acknowledge your references.	Science how-to p. 408
Scientists are working to reduce the carbon dioxide outputs from using biomass. Propose criteria to help them assess which biofuel production method is the best for reducing carbon dioxide.	Using forests as the basis for biomass material creates problems such as land clearing and release of carbon dioxide. Propose some strategies that scientists could use to solve these problems.	It is claimed that bioenergy is a more efficient energy source than other sources. Evaluate the evidence for this claim. You will need to undertake some research.	Science how-to p. 425

5 per cent of its energy from biomass, whereas many other countries produce about 7–10 per cent bioenergy.

Figure 1.41: This biomass factory creates biogas, which can be used as fuel.

Companies developing biomass projects in Australia need to consider a number of factors, including increased efficiency, lowered emissions and production costs, the creation of new technologies and reduced waste.

Focus area 2

2.0 Disease

All day, every day, our bodies interpret and respond to the world around us. Specific body systems help our internal systems remain in balance, even when our external environment continues to change. This not only allows us to move around and interact with our surroundings; it can also help the body to recognise and fight a range of diseases.

Figure 2.1: Several systems in our body help to keep us in balance, just like someone balancing on a slackline.

Learning Ladder

The Learning Ladder contains the scientific content and processes you will learn in this focus area. Each area has five levels of progression. To move to higher levels, you need to practise activities at the earlier levels. This will help you develop the ability to complete tasks that are more complex.

Steps in progression	Content	Working scientifically processes		Steps in progression
	Disease	**Analysing data and information**	**Communicating**	
5	I can analyse a range of disease prevention and management strategies for their effectiveness.	I can evaluate conclusions based on the quality of data.	I can evaluate scientific findings based on secondary evidence and arguments.	5
4	I can interpret data relating to body balance and health, and disease incidence and prevalence.	I can assess data and information for accuracy, reliability and validity.	I can present scientific findings using appropriate conventions for specific audiences.	4
3	I can explain how processes and functions can maintain balance and health or cause disease.	I can draw conclusions based on patterns in data and information.	I can construct a range of appropriate scientific presentations based on first-hand and second-hand data and information.	3
2	I can describe how specific mechanisms work to maintain balance and health in the body or cause disease.	I can explain relationships between datasets and information.	I can use digital technologies to organise and present data and information.	2
1	I can identify mechanisms that help to maintain balance and health or cause disease.	I can describe trends from collected data and information.	I can select appropriate ways to communicate information.	1

Figure 2.2: Scientists continue to study the brain to learn how it helps to keep the body in balance.

2·1 ► Homeostasis

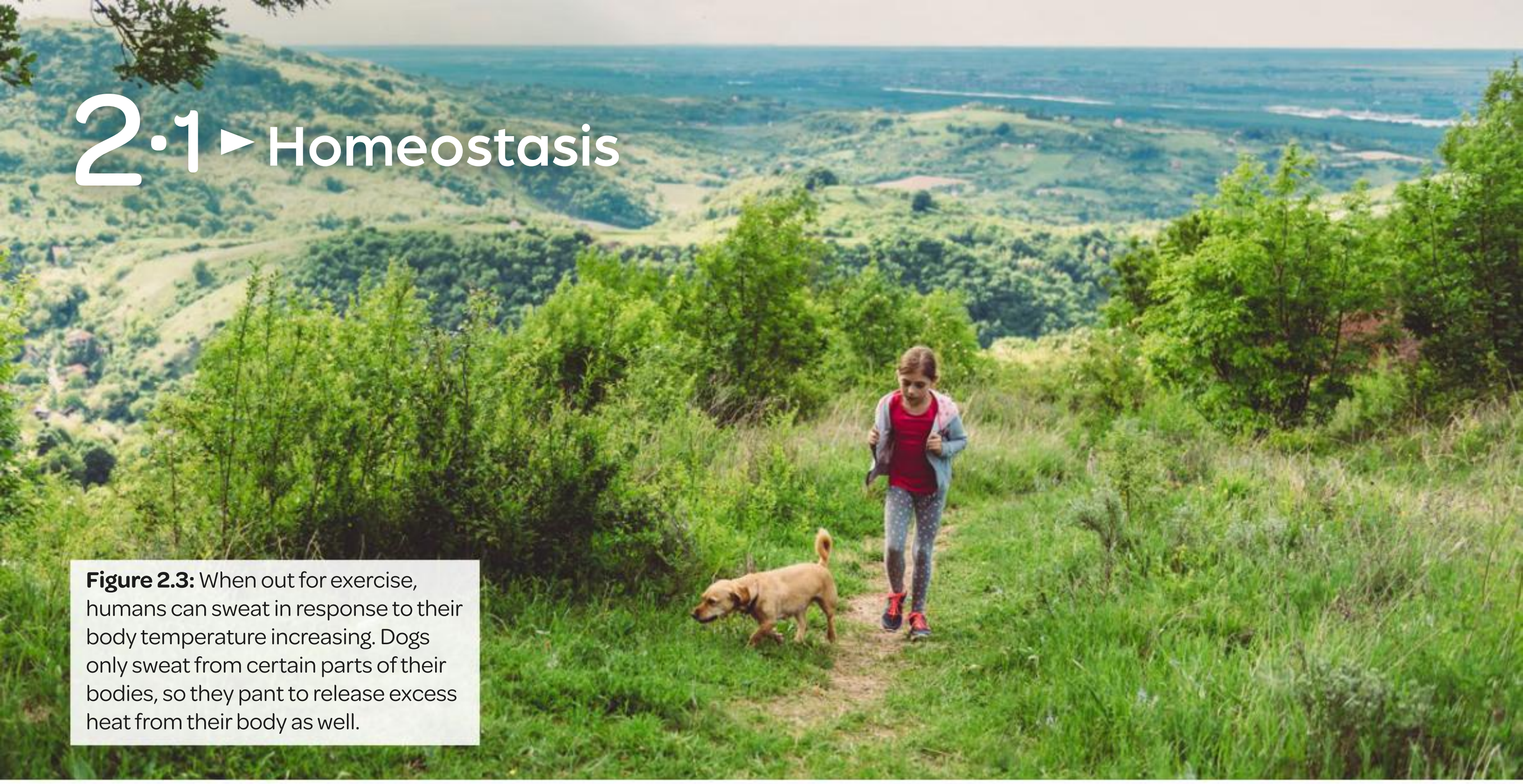


Figure 2.3: When out for exercise, humans can sweat in response to their body temperature increasing. Dogs only sweat from certain parts of their bodies, so they pant to release excess heat from their body as well.

Learning intention

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

- identify the importance of homeostasis
- describe examples of responses to stimuli.

Key terms

denature: to change the three-dimensional structure of a protein so that it no longer performs its function

enzyme: a protein that increases the rate of a specific chemical reaction in the body

homeostasis: maintaining a balanced internal environment, by responding to changes in the external environment

receptor: a specialised cell or organ that detects changes

stimulus (plural stimuli): a detectable change in the environment that can be detected by a receptor

Investigation 2.1A

Sensory receptors, page 486

Investigation 2.1B

Reaction time, page 488

Content group: Homeostasis

Multicellular organisms tend to have complex bodies, consisting of many organs and systems that work together. Human bodies react to changes by working to keep all the body systems in a state of homeostasis.

Many changes can affect the body

A change in the environment can affect the body. For example, if it gets hot, we sweat; if it gets cold, we shiver. Our bodies can also detect and respond to more subtle changes in the environment.

A physical change can affect the position of the body, such as when balancing on a beam. As you move back and forth to keep your balance, your body reacts so that you stay in control. Movement is another physical change; not only does your body change position, but parts of it, such as your feet, feel impacts as they push against surfaces.

Your body also reacts to chemical changes. Whenever you eat something, your body's systems react to the chemicals in the food. The food is broken down through a series of chemical processes, and the acquired nutrients are sent around the body to keep your cells functioning. If the food contains a toxin, your body can have an extreme response and leave you feeling quite unwell!

Receptors detect changes and trigger responses

When something changes in the environment around an organism, the first step is for the organism to detect the change. This is done through **receptors** – specialised cells and organs that can detect specific **stimuli**, which indicate the specific change that has occurred.

Sensory receptors can be classified into four broad categories:

- *Photoreceptors* respond to changes in light. In humans, photoreceptors are in the eyes.
- *Chemoreceptors* respond to different chemicals. The chemoreceptors in your tongue allow you to detect different flavours.
- *Thermoreceptors* respond to changes in temperature. In humans, most thermoreceptors are on the skin (Figure 2.4).
- *Mechanoreceptors* respond to changes in pressure or position. In humans, many of these are on the skin. Mechanoreceptors in the inner ear are vital for maintaining balance.

Once a receptor detects a change, it sends a message to the brain, which then targets the appropriate body systems and organs. These systems then respond to compensate for the change. Table 2.1 shows some responses to stimuli in different organisms.

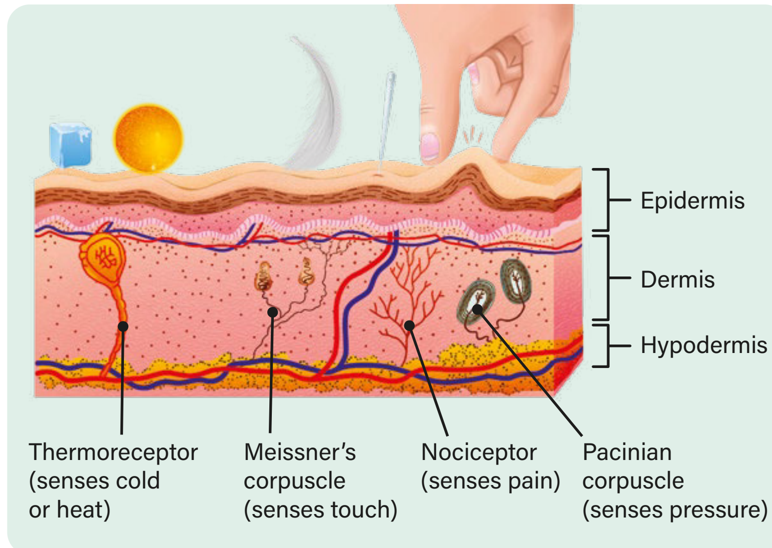


Figure 2.4: There are many different sensory receptors in the skin.

Table 2.1: Responses to stimuli observed in different organisms

Organism	Stimuli	Response
Human	Walking from a dark room into bright light	Constriction (getting smaller) of pupils to reduce the amount of light that enters the eye
Wombat	Smelling dingo faeces (poo)	Running back towards their burrow for shelter to avoid a predator
Kangaroo	Heat from the Sun on skin	Moving into a shady area and licking paws to allow the body to cool down

Homeostasis is the baseline state

Homeostasis is the 'normal' or baseline state of the body – the point at which every organ and system is working as it should. When the human body is at homeostasis, body temperature and pH, blood pressure, and glucose and oxygen levels are maintained at optimal levels.

If homeostasis is not maintained, organisms cannot function. Many processes in the body require precise temperature ranges. Specific **enzymes** within the body, like those that help us to break down and digest food, will **denature** and not function if the body warms up or cools down too much.

Learning Ladder

Disease

1. Identify two receptors that help to recognise stimuli that can affect the body.
2. For each receptor you identified in Question 1, describe the response that occurs to help maintain homeostasis.
3. Explain how regulating body temperature can help maintain homeostasis.

Communicating

see page 429

1. Describe a way you could visually present the information in Table 2.1 to your audience.
2. Construct your described communication method for one of the three examples presented in Table 2.1.
3. Using the information above, and from an additional secondary source, construct an infographic showing how humans respond to the cold.

In context

We can use technology to help the body function. Find a technology that can help a human respond to a stimulus and explain how it helps the body to maintain homeostasis.

Success criteria

- I can define homeostasis and identify why it is an important process in the body.
- I can give examples of how different organisms respond to stimuli.

2.2 ▸ Feedback loops

Learning intention

At the end of this lesson, I will be able to identify the role of feedback loops in maintaining homeostasis.

Key terms

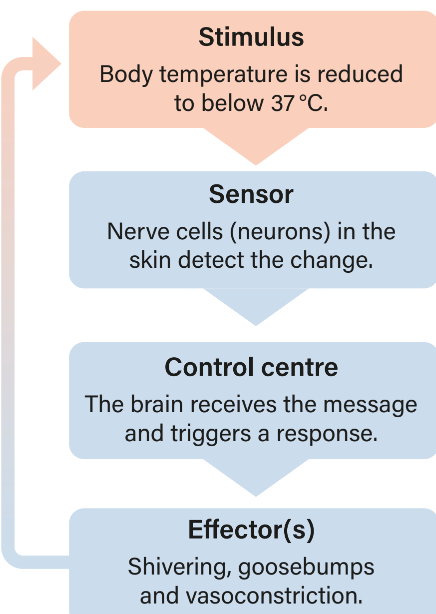
effector: a specialised cell, muscle, gland or organ that performs specific actions in response to a stimulus

negative feedback: a response that counteracts a stimulus

positive feedback: a response that amplifies a stimulus

vasoconstriction: the constriction of blood vessels

Content group: Homeostasis



▲ **Figure 2.5:** Feedback loops work by responding to stimuli to bring the body back to baseline conditions. This works for a lot of processes, including body temperature.

Changes occur all around us, all the time. These changes can affect how we react to the world. To help maintain homeostasis, our bodies have several feedback loops, which amplify or counteract changes we encounter.

Feedback loops work from a baseline

Many processes in the body have specific requirements for conditions such as optimal temperature and pH. An optimal level for a condition is referred to as a baseline.

This baseline is what feedback loops help to maintain. Receptors within the body can detect changes from the baseline. Messages are transmitted to the control centre of the body, which then transmits a message to **effectors**. The effectors then carry out a specific action to help return the body to baseline conditions.

Negative feedback loops counteract stimuli

Almost all feedback systems in the body are **negative feedback** loops. In a negative feedback loop, the response detected by receptors is transmitted to the control centre, which causes effectors to carry out actions that counteract the detected changes. This means that the body is actively working to prevent further change from occurring.

An example of this is maintaining temperature (Figure 2.5). The normal human body temperature is approximately 37 °C, although individuals can vary slightly. When a human is exposed to a lower external temperature than normal, this is detected by special receptor cells called neurons (see Section 2.3). These receptors transmit information about the reduced temperature to the control centre in the brain, which triggers effector cells in the muscles. The effectors cause us to get goosebumps and shiver and trigger **vasoconstriction** – the constriction of blood vessels. This helps to prevent heat loss. All these responses work together to bring body temperature back up, returning the body to normal conditions.

Table 2.2: Temperature ranges for some conditions of the body

Condition	Temperature (°C)	
Hypothermia	<35.0	
Low	35.1–36.0	
Normal/baseline	36.1–37.0	
Normal to low-grade fever	37.1–37.9	
Fever	38.0–39.4	
High fever	>39.5	

Figure 2.6: When it is cold, we often 'rug up' to keep warm. Negative feedback loops in our body cause us to get goosebumps and shiver, which is a response to return our body temperature to its baseline (37 °C).

There are several clinical conditions under which body temperature changes from normal. These are listed in Table 2.2.

Another condition that is controlled by negative feedback is blood sugar levels. Blood sugar levels are controlled by the hormones insulin and glucagon. When blood sugar levels become higher (e.g. after a meal), insulin sends a signal to the liver, muscles and other cells to take up the excess glucose (sugar) to be stored as body fat or as glycogen in the liver and muscles. When blood sugar levels are too low, the hormone glucagon signals the liver to break down glycogen into glucose, which enters the bloodstream and increases the levels back to normal.

Positive feedback loops amplify stimuli

Although most feedback loops in the body work to return the body to its baseline, a few special **positive feedback** loops amplify the initial stimulus detected by the body. This means that instead of returning to baseline conditions, the body moves further away from them.

An example of this is labour contractions. As the unborn baby moves into position for birth, contractions start in the mother. This causes the cervix to stretch, which in turn triggers more intense contractions, amplifying the process. This continues until after the baby is born, which interrupts the loop and stops the contractions from amplifying.

Learning Ladder

Disease

1. Identify two responses that help us maintain normal body temperature.
2. Describe how a positive feedback loop can be beneficial in the body.
3. Explain how a negative feedback loop works to maintain homeostasis in the body.
4. Consider the information in Table 2.2, and identify the temperature ranges considered to be:
   - **a** normal body temperature.
   - **b** hypothermia.
   - **c** fever.

Analysing data and information

see page 420

1. Describe the trend that occurs in labour contractions after they are initiated.
2. Explain the relationship between reduced body temperature and specific physical symptoms a person can experience.
3. You have a virus and have been feeling both hot and cold. You measure your temperature to be 37.6 °C. Explain a conclusion you can draw from this measurement.
4. Explain a way you could assess the data in Table 2.2 to determine how reliable it is.

In context

Many processes of the body rely on negative feedback loops. Conduct research into another negative feedback loop and explain how it works to maintain homeostasis. Include a diagram with your response.

Success criteria

- I can identify a feedback loop.
- I can describe how a named feedback loop helps maintain homeostasis.

2·3 ▸ The nervous and endocrine systems

Learning intention

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

- describe how the nervous and endocrine systems function
- compare and contrast the responses of the nervous and endocrine systems to stimuli.

Key terms

axon: a long fibre that is part of a neuron that carries electrical impulses away from a neuron

central nervous system: the brain and spinal cord

dendrite: a filament that is part of a neuron that receives the electrical impulse

gland: a tissue that secretes hormones

hormone: a chemical secreted by a gland that triggers a response in certain cells

neuron: a specialised cell that carries messages throughout the nervous system

neurotransmitter: a chemical messenger that carries a chemical message from one neuron to another

peripheral nervous system: the part of the nervous system that lies outside the brain and spinal cord

synapse: the gap between the axon and dendrite of two neighbouring neurons

Investigation 2.3

Sheep brain dissection, page 490

Content group: Homeostasis

When receptors respond to stimuli, they send 'messages' to different body systems to trigger changes and maintain homeostasis. These messages are complex chemical and electrical signals. These signals involve different systems interacting in many ways to respond effectively. This complex interaction is governed by the nervous and endocrine systems: the coordination systems of the body

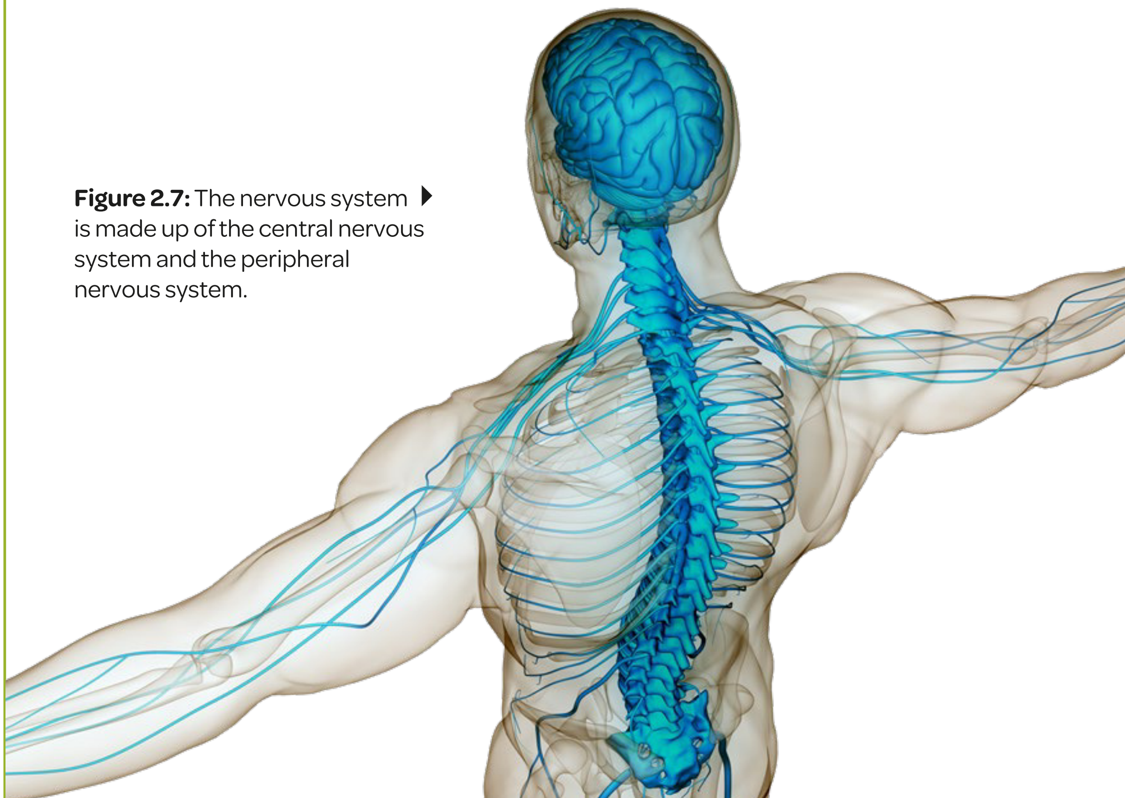


Figure 2.7: The nervous system is made up of the central nervous system and the peripheral nervous system.

The nervous system transmits signals around the body

The nervous system is a network of cells and fibres that transmits fast messages between parts of the body. It consists of billions of cells called **neurons**, which form long nerve fibres. There are several types of neurons and each plays a specific role. These roles are described in Table 2.3. The nerve fibres made up of neurons connect the brain to muscles and organs by sending messages in the form of tiny electrical impulses.

Neurons contain filaments called **dendrites**, which receive impulses, and long fibres called **axons**, which carry those impulses away from their cell body. Between one neuron and the next is a tiny gap called a **synapse**. When an electrical impulse reaches a synapse, it triggers the neuron to release chemical **neurotransmitters**. These neurotransmitters cross the synapse and stimulate the next neuron, so that the message continues to be transmitted (Figure 2.8).

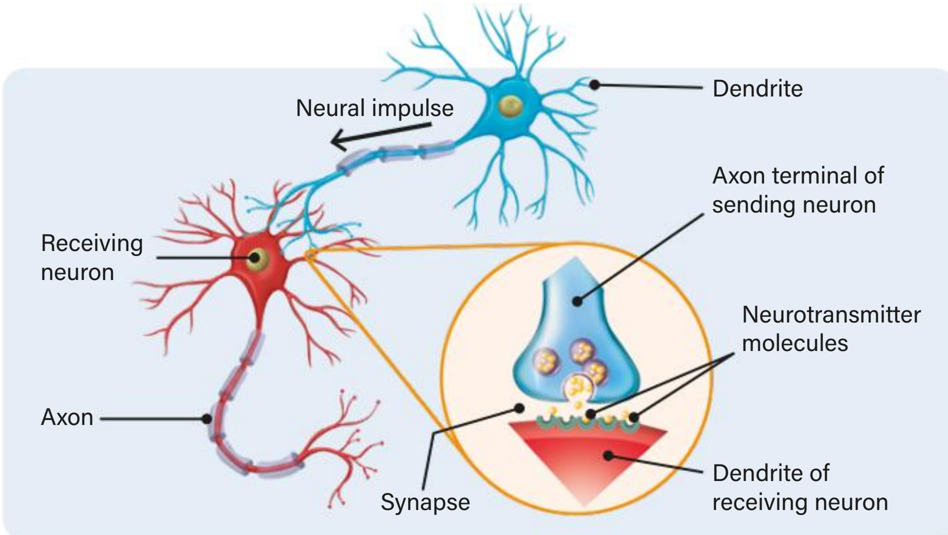


Figure 2.8: The axons and dendrites of neurons are separated by a gap called a synapse. The electrical impulse is translated into chemical neurotransmitters that cross the synapse and trigger the impulse to continue in the receiving neuron.

Table 2.3: Specialised types of neurons and their specific roles

Type of neuron	Function
Sensory	Detecting stimuli to allow us to feel sensations (e.g. contacting a hot surface with our hand)
Motor	Connecting muscles to the brain and controlling body movements
Interneuron	Connecting motor and sensory neurons to transmit messages

The nervous system supports conscious and subconscious responses

The nervous system of vertebrates, such as humans, is made up of two parts. The **central nervous system** consists of the brain and spinal cord. The **peripheral nervous system** is the network of nerves in the rest of the body, connecting it to the central nervous system.

The central nervous system is the 'control centre' of the nervous system, where all sensory information is interpreted so that it can give instructions to effector cells.

The peripheral nervous system has two main sections: the somatic nervous system and the autonomic nervous system. Each section has sensory and motor neurons, but they have different roles. The somatic nervous system controls conscious (voluntary) movement and responses, such as when you decide to kick a ball or move a pan off a stove top. The autonomic nervous system controls subconscious (involuntary) processes that happen automatically, such as our heart beating, breathing, and negative feedback loops for changes to external surroundings (e.g. temperature).

The endocrine system releases hormones

The endocrine system consists of multiple **glands** – groups of cells that produce complex molecules called **hormones** (Figure 2.9). Once the gland is triggered, it secretes hormones into the bloodstream to travel to target cells and trigger a response. Endocrine system responses are much slower than nervous system responses.

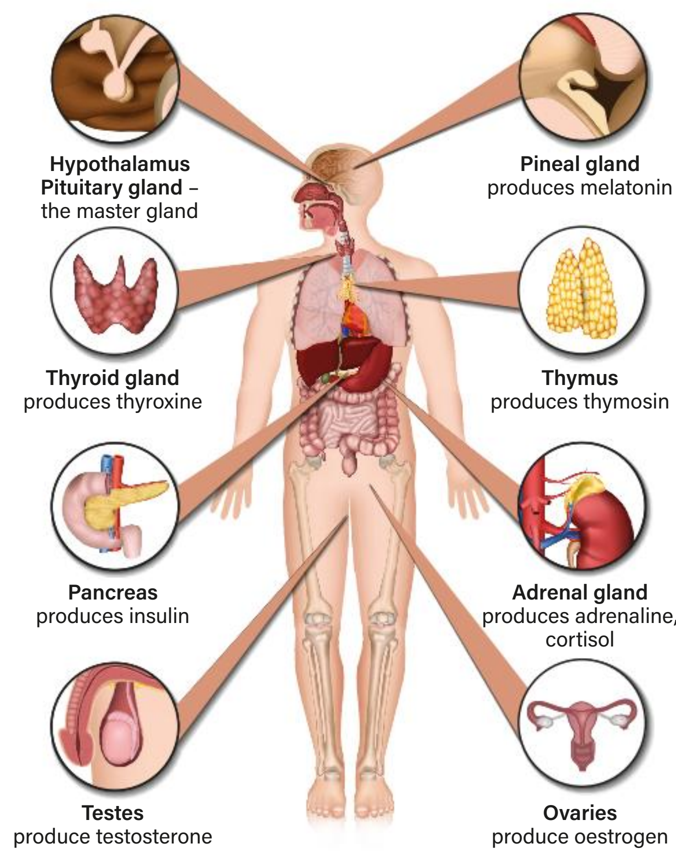


Figure 2.9: The endocrine system consists of specific organs that release hormones to help regulate body processes.

The pituitary gland is sometimes called the 'master gland' of the endocrine system. It sits at the base of the brain, just behind the bridge of the nose. Despite being only the size of a pea, it secretes hormones that control many other endocrine glands. It also secretes hormones that regulate growth and reduce feelings of pain.

Hormones produced by the pituitary gland include:

- **growth hormone** – affects height, and bone and muscle development
- **thyroid stimulating hormone** – triggers the thyroid gland to produce its own hormones
- **adrenocorticotrophic hormone** – stimulates the adrenal glands to release cortisol, which has widespread effects on organs and tissues in the body
- **follicle stimulating hormone** – acts on the reproductive systems of both males and females
- **luteinising hormone** – acts on the ovaries and testes and affects sexual development
- **prolactin** – affects development of mammary glands and milk production.

Specific organs release specific hormones

Hormones often act in pairs, one having the opposite effect to the other. These hormones are produced and secreted by specific organs and they play direct roles in helping our body to maintain homeostasis.

For example, blood sugar levels are controlled by insulin and glucagon, both produced in the pancreas. This example of a negative feedback loop was outlined in Section 2.2.

Other hormones that act in pairs to maintain homeostasis are:

- calcitonin and parathyroid hormone, which work to maintain calcium levels
- aldosterone and atrial natriuretic peptide, which maintain water levels in the body.

The nervous and endocrine systems work together

The nervous and endocrine systems coordinate the body's responses to changes in its internal and external environments. The brain plays a key role in both systems.

The brain has three main parts (Figure 2.10).

- The *cerebrum* is the largest part, consisting of two wrinkled hemispheres; this is where conscious thought takes place.
- The *cerebellum*, at the back of the brain, controls movement and balance.
- The *brain stem* connects the brain to the spinal cord and controls the automatic actions of the body.

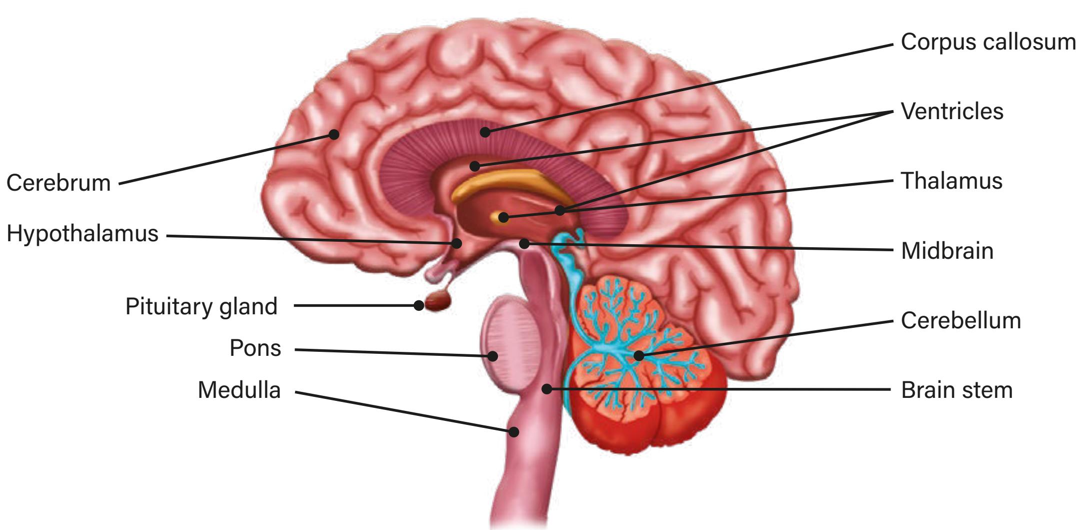


Figure 2.10: A cross-section of the human brain

At the centre of the brain is the *hypothalamus*, which is responsible for interpreting signals from all over the body to ensure homeostasis. It does this by sending chemical signals to the pituitary gland, telling the gland to release hormones that will bring the body back into balance.

An example of the nervous and endocrine systems coordinating is when we feel we are in a dangerous situation. Sensory neurons respond to a perceived threat and transmit the message to the hypothalamus, which sends a signal to the adrenal glands via interneurons. This causes the adrenal glands to release the hormone adrenaline, which prepares the body to respond immediately to the threat. For example, adrenaline acts on the heart to increase heart rate, which causes more blood to pump to the brain and muscles, and stimulates the body to make sugar for energy. For this reason, adrenaline is known as the 'fight-or-flight hormone'.

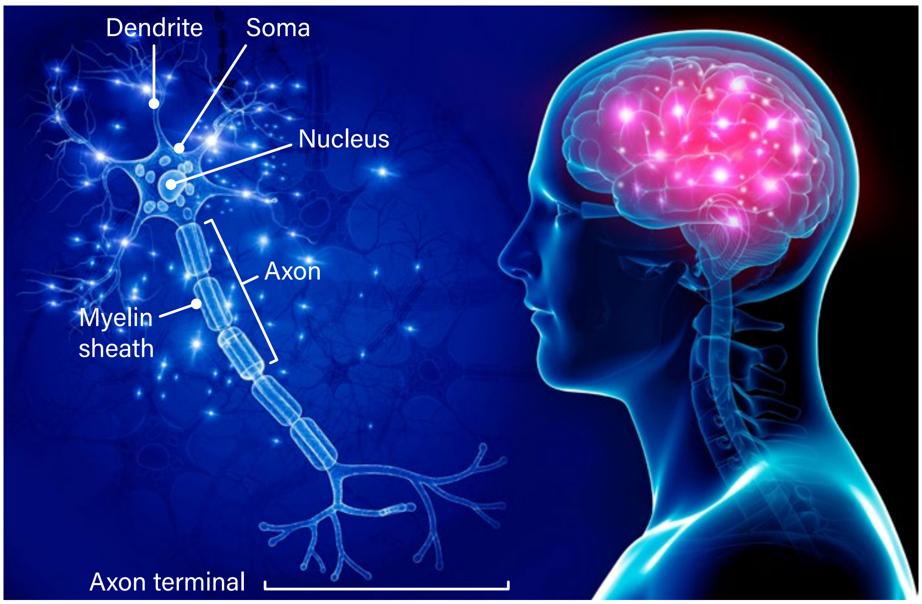


Figure 2.11: Neurons carry messages around the body and make up the brain so we can interpret signals and maintain homeostasis.

Learning Ladder

Disease

1. Identify five organs that produce hormones.
2. Describe each of the three types of neurons and the role they play in maintaining homeostasis.
3. Explain, using an example, why it is important for the nervous and endocrine systems to work together.
4. Propose a reason for the difference in speed between messages transmitted by the nervous system and those transmitted by the endocrine system.

Communicating

see page 429

1. Propose a way to present information on the endocrine system that would summarise the main organs and the hormones they produce.
2. Construct a digital table that identifies four different processes of the body that are controlled by the somatic and autonomic nervous systems.
3. Construct a labelled model of neurons that shows how a signal passes from one to another.
4. Use the information from this section to construct a digital presentation on the functions of the nervous and endocrine systems to show to a Year 6 student.

In context

There are many processes in the body that are controlled by the endocrine system. Find examples of two, and for each process identify the pair of hormones that work together and explain how they enable homeostasis to be maintained.

Success criteria

- I can describe how the nervous and endocrine systems function.
- I can compare and contrast the responses of the nervous and endocrine systems to stimuli.

2·4 ▸ Infectious diseases

Learning intention

At the end of this lesson, I will be able to identify a range of infectious diseases and their causes.

Key terms

host: a large organism that is infected by or harbours a smaller organism

incidence: the number of new cases of a disease in a population

pathogen: an organism that causes a disease in a host

prevalence: the total number of cases (new and existing) of a disease in a population

Content group: Infectious and non-infectious diseases

During winter, it seems as though most people are constantly coughing and blowing their noses. This is often because of one of the most common infectious diseases in existence – rhinovirus, or the common cold.

Infectious diseases can be transmitted

Unlike non-infectious diseases, infectious diseases are not limited to an isolated individual. Infectious diseases can be transmitted – passed from person to person – and spread rapidly through a population. COVID-19 spread around the world very quickly in 2020 because it is highly infectious – that is, it is easily transmitted between individuals.

When we talk about infectious disease numbers, we talk about the:

- **incidence** – the total number of new cases recorded in a population in a particular period
- **prevalence** – the total number of cases present, both new and existing, in that same time period.

The incidence rate of infectious diseases can increase rapidly as they are transmitted from person to person.

Infectious diseases are caused by pathogens

Small agents called **pathogens** are responsible for infectious diseases. Pathogens enter and replicate inside a **host** (e.g. humans), in turn causing the symptoms associated with the infectious disease.

Pathogens include microorganisms such as bacteria, viruses, fungi, prions and protozoa, and macroorganisms like parasites, such as tapeworms. Each pathogen has different characteristics and is responsible for specific infectious diseases.

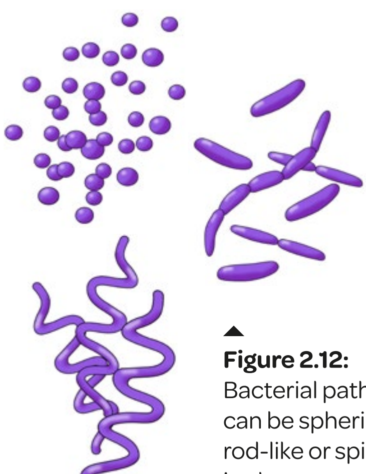


Figure 2.12: Bacterial pathogens can be spherical, rod-like or spiral in shape.

Not all microorganisms are pathogens

Even though bacteria and fungi are responsible for many infectious diseases, they are not *all* pathogens! The day-to-day functioning of our bodies is maintained partially by our microbiome – a collection of useful microorganisms that assist us with different processes. This includes preventing pathogens from entering our body and helping other processes such as digestion.

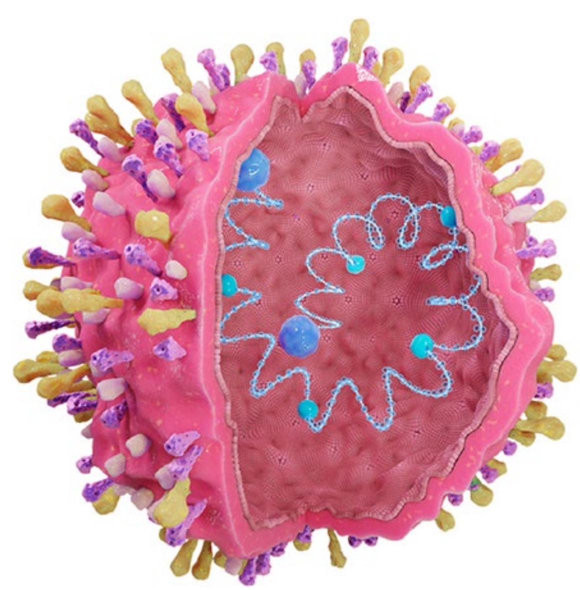


Figure 2.13: Viruses, such as those that cause colds, influenza and COVID-19, encase genetic material inside a protective protein coating.

Figure 2.14: Fungal pathogens can cause skin infections such as ringworm.

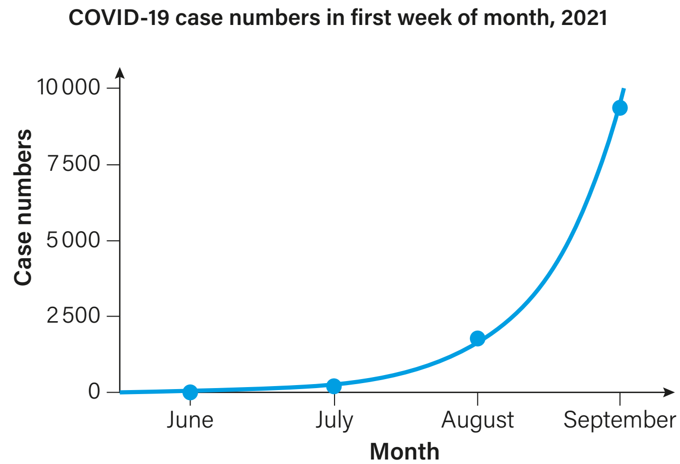


Figure 2.15: Data showing case numbers of COVID-19 in Australia during lockdown over four months of 2021

Table 2.4: Some infectious pathogens and the diseases they cause

Pathogen	Description	Diseases caused by pathogen
Bacteria	A prokaryotic unicellular microorganism that can be different shapes. All bacteria have a cell wall, and some have cilia or flagella for movement.	Meningococcal disease Whooping cough Cholera
Virus	A segment of DNA that is protected by a coat of protein. These pathogens cannot survive outside of a host for long periods of time.	Common cold Influenza COVID-19
Fungi	A eukaryotic (has a nucleus) unicellular microorganism with a thick cell wall that can be difficult to kill.	Ringworm Tinea (athlete's foot) Aspergillosis
Protozoa	A prokaryotic (does not have a nucleus) unicellular microorganism without a cell wall. Some protozoa have flagella for movement.	Malaria Toxoplasmosis
Prion	A malformed protein that can establish inside a host and cause more copies of itself to be formed.	Creutzfeldt-Jakob disease Kuru
Macroparasite	A small animal that enters hosts and lives inside them, feeding off them or the nutrients they consume.	Tapeworm infection Nematode infection

Learning Ladder

Disease

1. Identify three pathogens that cause infectious diseases.
2. Describe the features of one of the pathogens you identified in Question 1 and name a disease it can cause.
3. Explain why the incidence of infectious diseases can often rise significantly faster than the incidence of non-infectious diseases.
4. Based on the graph in Figure 2.15, how many cases of COVID-19 would you expect to see in October?

Analysing data and information *see page 420*

Consider the graph in Figure 2.15.

1. Describe the trend seen in the graph.
2. Explain the link between the infectiousness of COVID-19 and the case numbers seen in the graph.
3. Construct a conclusion based on the data shown in the graph.
4. Assess the reliability of the data in the graph.

In context

Select an infectious disease from this section and construct an infographic to inform the public about the pathogen that causes the disease, the symptoms they should watch for and the treatments available.

Success criteria

- I can identify a range of infectious diseases.
- I can describe the types of pathogens responsible for a range of infectious diseases.

2.5 ▸ Non-infectious diseases

Learning intention

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

- distinguish between infectious and non-infectious diseases
- identify a range of non-infectious diseases and their causes.

Key terms

disease: a disorder that causes negative symptoms or outcomes in a living thing

environmental factor: an agent that is present in a person's surroundings

genetics: a trait or characteristic that is passed from a parent to an offspring

infectious: can be transmitted between individuals

non-infectious: cannot be transmitted between individuals

nutrition: the intake of nutrients that are necessary for health and growth

transmission: spreading from person to person

Investigation 2.5

Cardiovascular disease in Australia, page 492

Content group: Infectious and non-infectious diseases

At some time, all of us can be affected by disease – a disorder that causes the negative symptoms that we associate with illness.

Diseases can be infectious or non-infectious

Disease affects our ability to function and perform day-to-day activities. This function is altered as a result of symptoms – specific physical responses and experiences – which can be mild (like a runny nose) or severe (such as the shortness of breath and rapid heart rate associated with heart disease).

Symptoms can differ greatly, as can the causes of diseases. Some diseases, such as those caused by bacteria and viruses, are **infectious**. Others, like heart disease and diabetes, are **non-infectious**.

Non-infectious diseases cannot be transmitted

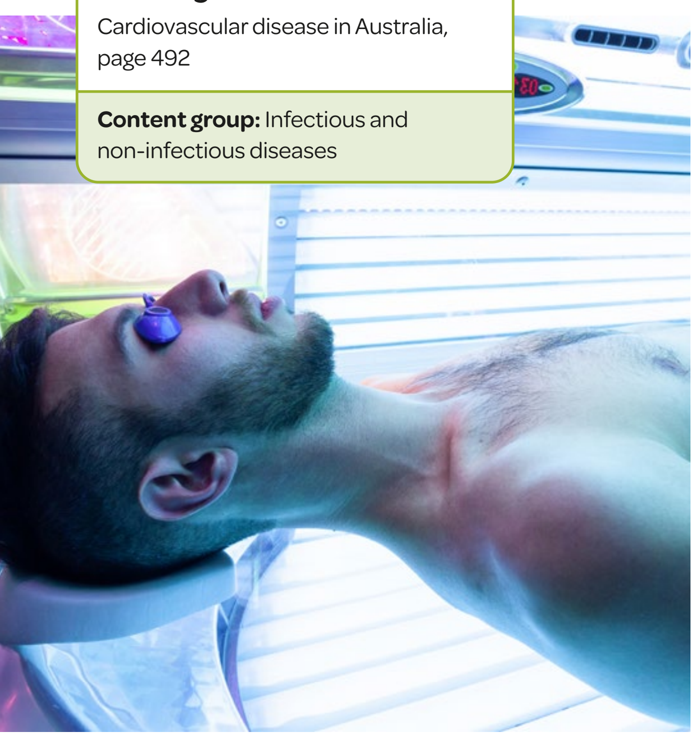
Someone can develop a non-infectious disease over time or be born with it. When individuals are diagnosed with a non-infectious disease, we do not need to look for the disease in the people around them because non-infectious diseases are not spread by **transmission** from person to person.

A range of factors can cause non-infectious diseases

Non-infectious diseases have many causes, including genetic, environmental factors and nutrition. Some non-infectious diseases that can result from these causes are shown in Table 2.5.

Genetics are traits that are passed from parents to their children. A child inherits these traits from the egg and sperm cells of their biological parents. If one or both parents' sex cells have genes for a non-infectious disease, their child may inherit and display the trait for the disease.

Environmental factors are factors that individuals are exposed to in their surroundings, such as sunlight, the particles and pollution we breathe in from the air, and even noise and weather conditions. If we are exposed to too much of a particular environmental factor, we can develop a non-infectious disease such as skin cancer (Figure 2.16).



▲ **Figure 2.16:** Tanning beds used to be available in Australia. Commercial tanning beds are now illegal because the ultraviolet light from them is linked to an increased risk of skin cancer.

Nutrition is directly linked to the food and drink we consume every day. By eating a balanced diet, we are ensuring that our bodies receive the correct amount of specific nutrients and minerals. If we do not consume enough nutrients, it can result in vitamin or mineral deficiencies that can lead to a variety of non-infectious diseases, such as rickets (Figure 2.17).

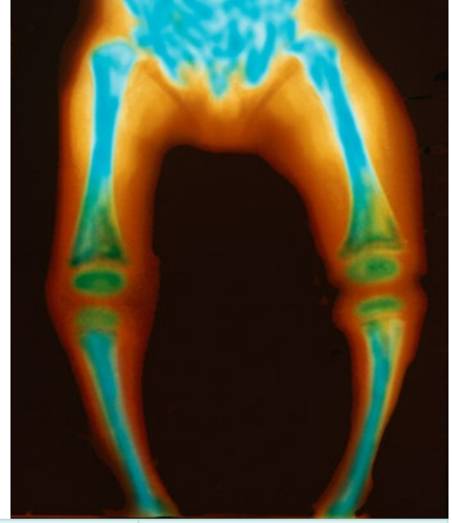


Figure 2.17: Bowed legs is a symptom of rickets, a disease in children caused by a lack of vitamin D.

Table 2.5: Some examples of non-infectious diseases in Australia

Disease	Description	Cause	Number of people affected in 2022
Down syndrome	Causes intellectual disabilities, health problems and muscular dystrophy	Genetic: an extra chromosome 21	14 000
Cystic fibrosis	Thicker than normal mucus causes damage to respiratory and digestive systems	Genetic: an inherited gene	3738
Skin cancer	Damage to skin cells causes them to mutate and grow abnormally	Environmental: overexposure to sunlight (ultraviolet radiation)	152 067
Asthma	Inflammation and tightening of the muscles of the airway, production of extra mucus, making it hard to breathe	Environmental: exposure to triggers such as pollen from the surrounding environment	2.8 million
Rickets	Bones fail to develop properly and soften, causing them to bow outwards	Nutritional: vitamin D deficiency	250
Hyperlipidaemia	High cholesterol levels in the body	Nutritional: over-consumption of alcohol or fatty foods	2.1 million

Learning Ladder

Disease

1. Identify one way to prevent yourself from developing a non-infectious disease caused by a poor diet.
2. Describe a way that you could prevent one of the named diseases in Table 2.5.
3. Explain how genetics can result in a non-infectious disease in a child.
4. The population of Australia in 2022 was approximately 26 million. Use the data in Table 2.5 to calculate the percentage of Australians who have:
   a asthma. **b** hyperlipidaemia. **c** skin cancer.
   More information about performing calculations is available in the Science how-to section on pages 446–62.

Analysing data and information

see page 420

The Australian Bureau of Statistics lists dementia as the second leading cause of death in Australia for the last 12 years. Number of deaths are: 10 965 in 2013, 13 991 in 2017, 15 957 in 2021, and 17 106 in 2022.

1. Describe the trend in this data.
2. Convert the data into a graph. What can you infer about dementia-related deaths in Australia?
3. Propose a conclusion you could draw from your graph.
4. Assess the data on dementia-related deaths for its validity. More information about scientific writing is available in the Science how-to section on pages 433–45.

In context

Identify another non-infectious disease. Conduct research into the cause of this disease and investigate how many people in Australia had the disease last year.

Success criteria

- I can distinguish between infectious and non-infectious diseases.
- I can identify a range of non-infectious diseases and their causes.

2·6 ▸ Infectious disease transmission

Learning intention

At the end of this lesson, I will be able to explain the different transmission methods of a range of infectious diseases.

Key terms

direct contact: a method of diseases transmission from one person to another

intermediary: a link between two hosts that allows a pathogen to move indirectly between them

vector: an organism that carries a disease-causing agent from reservoirs to the host

Investigation 2.6A

Modelling direct disease transmission, page 493

Investigation 2.6B

Modelling indirect disease transmission, page 495

Content group: Infectious and non-infectious diseases

We cannot contract a non-infectious disease from the person sitting next to us, but we can contract an infectious disease from them. We know that infectious diseases can be transmitted within a population – but how does this happen?

Direct transmission is from person to person

One method of disease transmission is known as **direct contact**. This is when a disease is passed directly from one person to another person. Disease pathogens travel from the infected individual onto the uninfected individual, and then attempt to make their way into the body.

Some methods of direct contact are:

- shaking hands or high-fiving – the pathogen moves from one hand to another
- hugging – the pathogen is transferred at points of contact
- kissing – the pathogen travels through the exchange of saliva
- sexual intercourse – the pathogen travels through the exchange of bodily fluids.

Many diseases are transmitted in this way. For example, mononucleosis, more commonly known as glandular fever, is sometimes called 'the kissing disease' because it is transmitted by the exchange of saliva.

Indirect transmission involves an intermediary

Some diseases do not require direct contact between infected and non-infected individuals. These diseases can be transmitted by indirect contact, or a secondary surface or medium – an **intermediary**. This means that the pathogens can survive outside the infected host for some time (hours, days, weeks or even years) and be picked up by non-infected individuals who make contact with the surface or medium.

Some methods of indirect contact are:

- airborne – the pathogen is expelled into the surrounding air, often by coughing or sneezing, and remains in the air for a period of time
- waterborne – the pathogen can remain in waterways and infects people when they consume the water
- food contamination – the pathogen lives on food surfaces and infects people when they ingest the food
- surface contamination – the pathogen settles on surfaces and is picked up when a person touches the surface
- vector – an insect or animal transfers the pathogen through a bite, or through contact with their urine, faeces or blood.

Figure 2.18: Chickenpox is an infectious disease that is spread when uninfected individuals contact blisters on the skin of an infected person.

Animals can act as vectors

Vector transmission, although a form of indirect contact, is a very specific way for diseases to be transmitted. This form of transmission relies on animal hosts (or reservoirs) that carry the pathogen but are unaffected by it. When these hosts encounter and bite a human, they pass on the pathogen, and the human becomes infected with the disease.

For many vector-transmitted diseases, human-to-human transmission rates are extremely low. An example of this is malaria, which resides in the bloodstream of humans after they are bitten by mosquito carriers of the disease. The only way malaria could be transmitted from one human to another would be through their blood or organs being given to another person, or through sharing syringes.

▲ **Figure 2.19:** Even though you cannot see them, water sources can contain harmful pathogens that cause illness if consumed. For example, the bacterial pathogen *Vibrio mimicus* can cause gastric upset. Sometimes warning signs are placed near contaminated water sources.

Table 2.6: Examples of diseases that can be transmitted by direct and indirect contact

Method of transmission	Diseases that can be transmitted this way
Direct	Chickenpox Conjunctivitis Cold sores (herpes simplex)
Indirect	Cholera – food and water transmission Influenza – airborne and surface transmission Tuberculosis – airborne transmission
	Vector: Malaria – mosquito bites Bubonic plague – flea bites

▲ **Figure 2.20:** Shaking hands can spread pathogens from an infected individual to a new, healthy host.

Learning Ladder

Disease

1. Identify two methods of direct contact disease transmission.
2. Describe a form of indirect contact transmission.
3. Explain how an animal can transmit a specific disease to humans.

Communicating

see page 429

1. Propose one way you could inform the public about how diseases can be transmitted from person to person.
2. Describe an online medium you could use to organise your information for the task in Question 1.
3. Construct your suggested way of communicating information. Use your responses to Questions 1 and 2 to determine what software to use and what information to include.
4. Take turns to present your information in small groups. The groups should offer each presenter two pieces of specific feedback on their presentation: one thing they liked, and one thing they wished they had heard or seen.

In context

Use secondary research to find another two diseases – one that is transmitted through direct contact and one through indirect contact. Explain the symptoms of these diseases and link these symptoms to their methods of transmission.

Success criteria

- I can explain the different methods by which infectious diseases are transmitted between individuals.

2·7 ▸ Epidemics, endemics and pandemics

Learning intention

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

- define the terms 'epidemic', 'endemic' and 'pandemic'
- use specific examples to compare the features and incidence rates of epidemics, endemics and pandemics.

Key terms

endemic: an outbreak of a disease in a specific geographical area

epidemic: an outbreak of a disease in several populations in one geographical area

outbreak: a sudden spike in the number of cases of a disease

pandemic: an outbreak of a disease in multiple populations in different geographical locations across the world

Content group: Infectious and non-infectious diseases

The rapid outbreak and transmission of infectious diseases such as COVID-19 can have worldwide impacts, quickly becoming pandemics if they are not well contained.

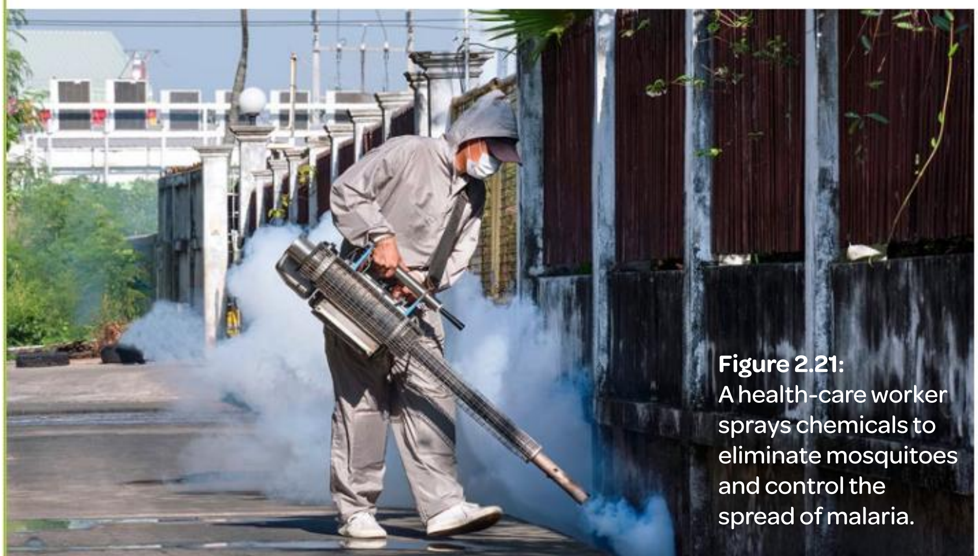


Figure 2.21: A health-care worker sprays chemicals to eliminate mosquitoes and control the spread of malaria.

Endemic diseases are confined to specific populations

Some diseases occur in specific populations or regions. These diseases are known as **endemic** diseases. When a disease is endemic, its spread and rates are predictable, and the disease can usually be contained. Malaria is an endemic disease that consistently occurs in South-East Asian regions.

Figure 2.22: ▸ Malaria is endemic to many regions in South-East Asia, Africa and South America.

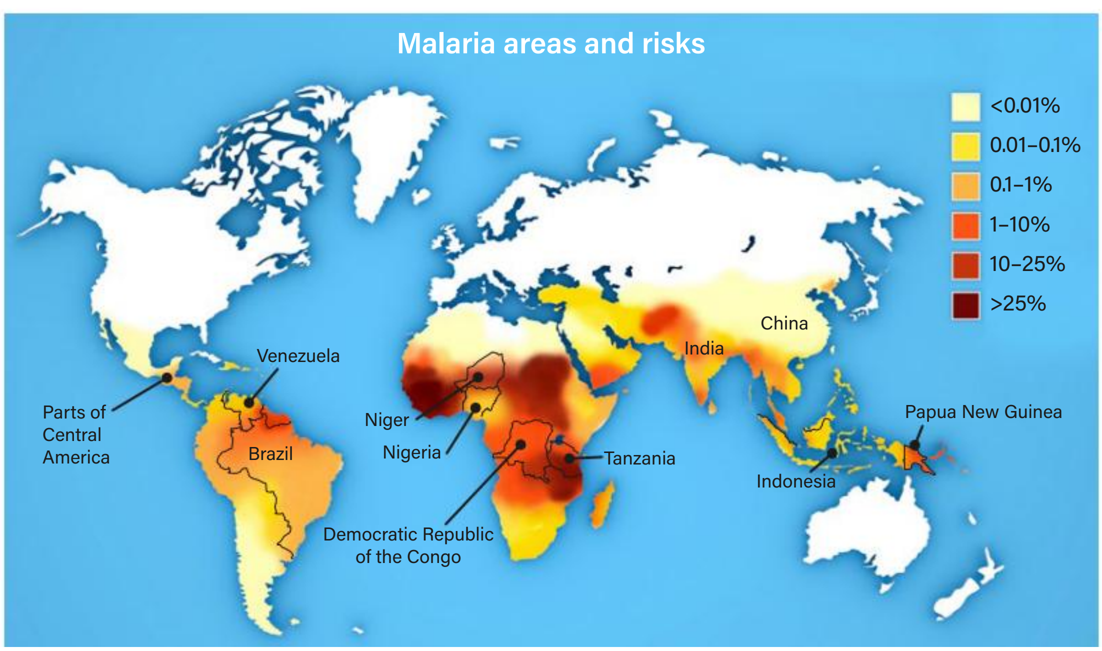


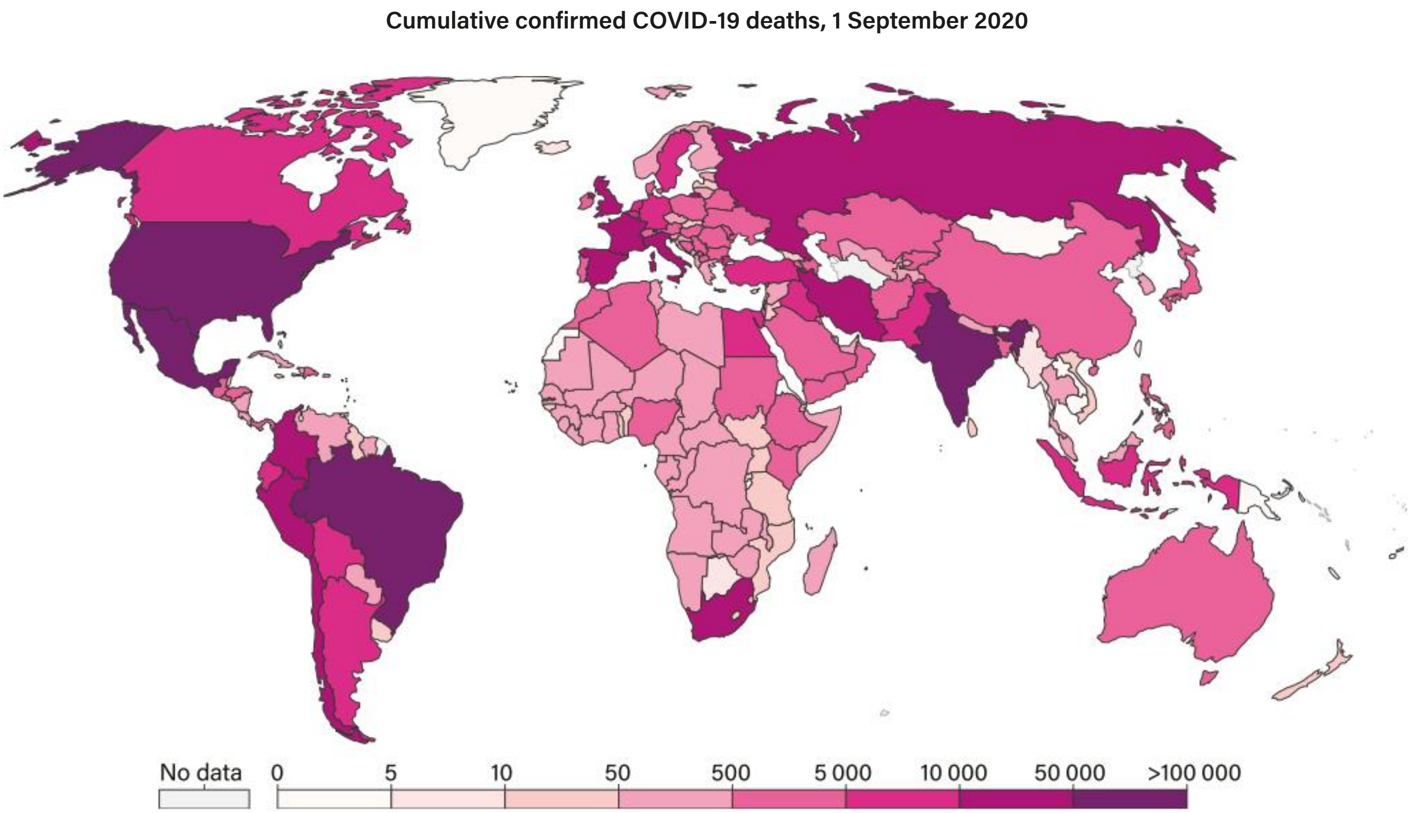
Figure 2.23: Ebola virus was fatal in 39 per cent of cases during the West African epidemic of 2014–16.

Epidemics occur across several populations

Epidemics are more unexpected than endemic diseases. Sudden, unexpected **outbreaks** of a disease in a singular population, that can spread across a specific region, are considered to be epidemics.

The West African Ebola epidemic occurred from 2014 to 2016. Cases of Ebola were found in several populations in Guinea, Liberia and Sierra Leone.

Ebola is caused by a virus that is spread through direct transmission when non-infected individuals come into contact with the body fluids of infected individuals. The disease can also be spread by contact with things an infected person has touched, such as clothes or bedding. It can also be spread by contact with infected animals (e.g. when preparing, cooking or eating them). This epidemic spread rapidly as family members came into contact with infected individuals, even after they had died. Infected individuals started to have symptoms of fatigue, headaches and body aches. As the disease progressed, some people developed vomiting, diarrhoea and internal bleeding, which caused death in 39 per cent of cases. The sudden onset and rapid spread meant it took two years for the epidemic to be declared over.



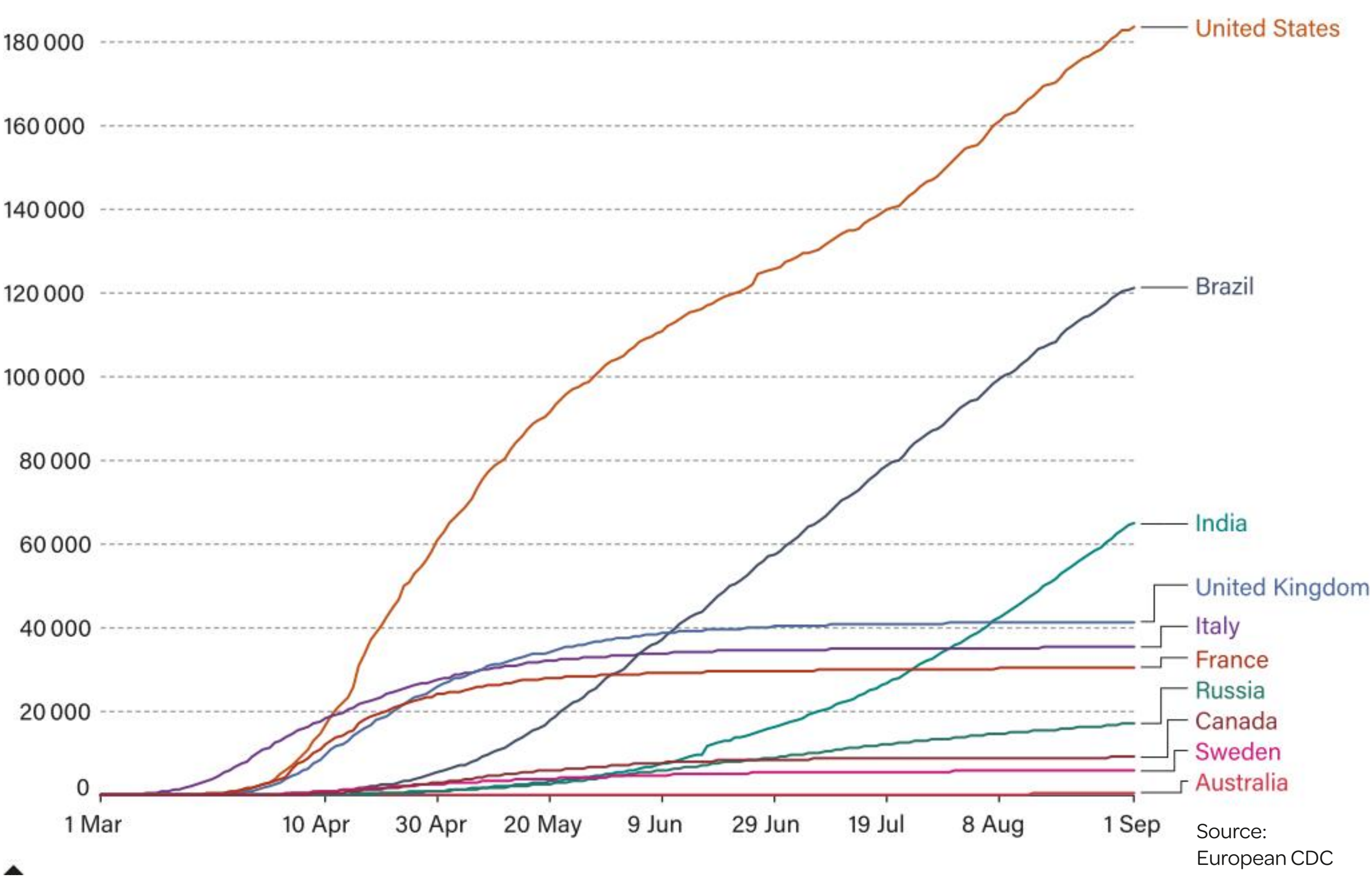


Figure 2.24: COVID-19 became a pandemic and spread rapidly across the world in early 2020. The worst-affected countries were the United States and Brazil.

Pandemics are the result of global disease spread

When a disease outbreak rapidly becomes an epidemic and is not effectively contained, it can progress and become a **pandemic**. Pandemics are diseases with rapid transmission and infection rates that occur across many countries simultaneously.

An example of a pandemic is COVID-19. In December 2019, a new strain of coronavirus was identified in Wuhan, a city of 11 million people in central China. Chinese officials began to warn the rest of the world that the virus was spreading and multiplying extremely quickly. Many factors, including international travel and improper hygiene, caused the virus to spread within weeks to many countries, and so the COVID-19 pandemic (also known as the coronavirus) was introduced to the world. COVID-19 is the name of the disease, but the virus that causes the disease is SARS-CoV-2.

Preliminary research identified that SARS-CoV-2 has a zoonotic (animal) origin. Genetic testing found it to be similar to bat-borne viruses, which suggests that it originally came from bats (though it may have spread to humans through another animal). The virus spreads from person to person in several ways, including through respiratory droplets such as those from coughs or sneezes. It can also be spread via surfaces, as it lasts for up to three days on shiny surfaces such as plastic. Symptoms include a cough, fever and shortness of breath, but some people are asymptomatic – they show no symptoms.

The rapid spread of COVID-19 means that, since its discovery, it has continued to be found in countries all over the world. It grew from a singular, localised outbreak, to an epidemic, before becoming a pandemic, and remains active to this day.

Learning Ladder

Disease

1. Identify a disease that is or has been considered:
   a an endemic.
   b an epidemic.
   c a pandemic.
2. Describe the factors that make a disease endemic.
3. Explain the difference between an endemic, an epidemic and a pandemic.
4. Consider the map in Figure 2.22. Which regions have the largest number of malaria cases? Justify your response.
5. Propose a reason for the outfits the workers are wearing in Figure 2.23 in the midst of an Ebola epidemic.

Analysing data and information

see page 420

Consider the graph in Figure 2.24.

1. Describe a trend in the graph.
2. Explain the relationship between early case numbers and deaths.
3. Draw a conclusion about the order in which COVID-19 spread to different countries.
4. Use secondary sources to assess the reliability of the data presented in Figure 2.24. Explain any changes you would make.
5. Consider the conclusion you drew in Question 3, and evaluate its effectiveness based on your data assessment.

In context

COVID-19 is not the first pandemic to affect the world. Find another example of a pandemic and explain the disease, including its symptoms, transmission and fatality rate. What factors caused it to spread so widely around the world?

Success criteria

- I can define the terms 'endemic', 'epidemic' and 'pandemic'.
- I can compare the features and incidence of endemics, epidemics and pandemics.
- I can give a specific example of an endemic, an epidemic and a pandemic.

2.8 ▸ The immune system

Learning intention

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

- identify how the body can prevent the entry of pathogens
- describe how the body responds to invading pathogens.

Key terms

adaptive immune system: specific disease responses that target individual, recognised pathogens

antibody: a protective protein produced by the immune system to neutralise a specific infectious pathogen

chemical barrier: a defence that can kill pathogens that land on or attempt to enter the body

immune system: a network of cells and tissues that help to prevent and fight diseases in the body

innate immune system: general mechanisms of the immune systems that target any foreign substances in the body

line of defence: the different levels of defence that the body mounts to prevent and destroy infectious diseases

lymphocyte: a white blood cell that can produce antibodies and destroy infected body cells

phagocyte: a white blood cell that engulfs and ingests foreign particles and pathogens

physical barrier: a mechanism that blocks a pathogen from entering the body

Content group: Infectious and non-infectious diseases

Our **immune system** protects us from disease. However, sometimes pathogens can get past our defences or even attack or hijack our immune system, turning it against us. The immune system has three lines of defence to protect us from diseases.

The first line of defence is prevention

The first mechanism for protecting against disease – the first '**line of defence**' – is prevention. There are barriers to prevent infectious diseases and harmful foreign particles from entering the body.

- **Skin** is a **physical barrier** that blocks pathogens from entering the body. If you cut or injure yourself, the circulatory system works to quickly seal these breaches by forming clots at the site of cuts.
- **Mucous membranes** line the respiratory tract, nasal passages and female reproductive tract. Mucus traps particles that enter (e.g. when you breathe in surrounding air).
- **Nasal passages** are lined with tiny hairs called cilia, which help mucus to trap pathogens that are inhaled.
- **Tears and saliva** contain special antimicrobial substances that can kill pathogens.
- **Acidic gastric juices** – contain hydrochloric acid and can destroy pathogens that are ingested.

Sometimes pathogens can evade these barriers. When they do, they are met with some of the body's internal defences.

The second line of defence engulfs foreign substances

If pathogens evade the physical and **chemical barriers** of the first line of defence, they then meet the second line of defence. The second line of defence involves white blood cells called **phagocytes** that recognise foreign substances within the body (Figure 2.25). When the body detects a breach to the skin such as a cut, specialised cells release chemical signals to the rest of the body. These signals cause more phagocytes to travel to the infected area to help destroy any pathogens present. Phagocytes engulf any foreign particles and destroy them by using special chemicals to break them down and digest them. This also causes inflammation.

The release of these chemical signals can also trigger a fever. When the body temperature is slightly raised, cells divide more quickly, producing additional phagocytes to help fight off invading pathogens.

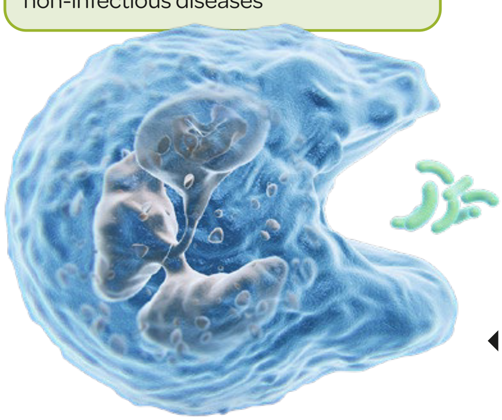


Figure 2.25: A white blood cell engulfing bacteria by phagocytosis. This is part of the body's second line of defence against disease.

The third line of defence targets and destroys specific diseases

Sometimes, even with the first two lines of defence, the body can become overrun with a particular pathogen. This is when the third line of defence is useful. Unlike the first and second lines of defence, which make up our **innate immune system**, the third line of defence is an **adaptive immune system**. This means it can remember and target specific pathogens that have infected the body. When a foreign pathogen enters the body, it is recognised by specialised white blood cells called **lymphocytes**. Different lymphocytes carry out different roles in response to a pathogen.

B lymphocytes produce **antibodies** as a response to the pathogen, which encourage cells of the immune system to kill the pathogen. T lymphocytes look for body cells that have been infected by the pathogen and destroy them. After the pathogen has been destroyed, special memory cells remain, ready for next time the body is infected by the same pathogen. The cells 'remember' the pathogen, meaning that if you are infected in future, your immune system can destroy it before you get sick. This makes you immune to that specific disease.

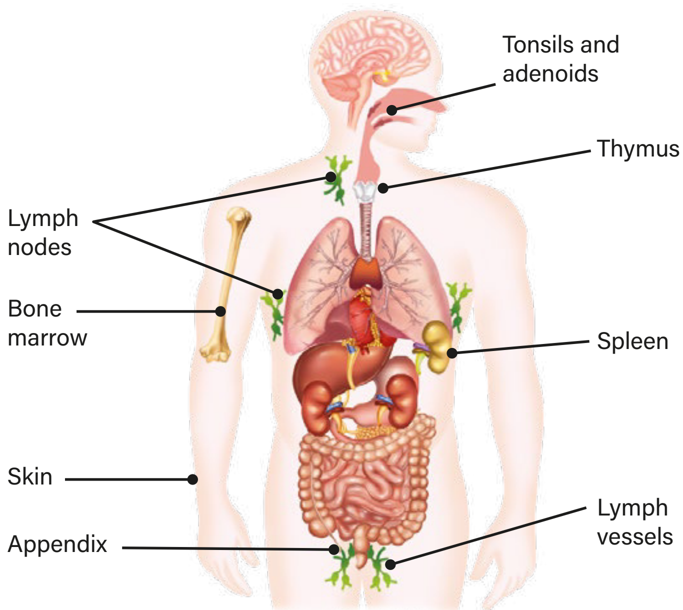
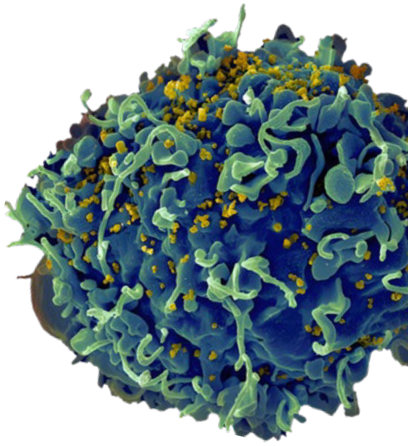


Figure 2.26: Many organs are involved in the human immune system.

Figure 2.27: An electron micrograph showing the human immunodeficiency virus (HIV) attacking a white blood cell of the human immune system. Left untreated, HIV usually leads to acquired immunodeficiency syndrome (AIDS). AIDS is potentially fatal, as the immune system cannot fight it off.



Learning Ladder

Disease

1. Identify a component of the immune system that can:
   - **a** provide a physical barrier.
   - **b** chemically destroy any pathogen.
   - **c** engulf many pathogens.
   - **d** stop a specific infectious pathogen.
2. Describe the second line of defence.
3. Explain how the immune system adapts to fight specific pathogens.
4. Children can get on average 12 respiratory infections a year, whereas adults average four. Propose a reason for this difference in the number of infections.
5. Analyse the effectiveness of the immune system in preventing and managing infectious diseases.

Communicating *see page 429*

1. Select an appropriate way to communicate the different components of the first line of defence.
2. Use a device to construct a digital version of your presentation method from Question 1.
3. Conduct secondary research into B and T lymphocytes, and construct a table summarising their roles in the immune system.
4. Share your presentation from Question 2 with one of your peers, and review their presentation, comparing it to yours. Provide two specific pieces of feedback that would improve their presentation.

In context

Select an infectious disease that you find interesting. Conduct research into this disease and explain how it enters and infects the human body. How does the immune system prevent and fight this disease?

Success criteria

- I can identify the physical and chemical barriers of the body that prevent pathogen entry.
- I can describe the lines of defence provided by the human immune system.

2.9 ▸ How vaccination works

Learning intention

At the end of this lesson, I will be able to outline how vaccinations work.

Key terms

herd immunity: the indirect protection from an infectious disease that happens when many people in a population are immune either through vaccination or previous infection

neutralise: a response that defends the body from a pathogen by stopping its effects without destroying it

vaccination: the introduction of a dead or weakened form of a pathogen into the body so that it can produce antibodies that will fight off future infections

Investigation 2.9

The contagion game, page 496

Content group: Infectious and non-infectious diseases

The adaptive immune system helps to protect us from several specific infectious diseases. However, for it to work, we need to have been previously exposed to a pathogen. This is how vaccination works – it exposes us to the pathogen without making us sick, so when we encounter the disease in the community, our immune system can fight off the disease before we become unwell.

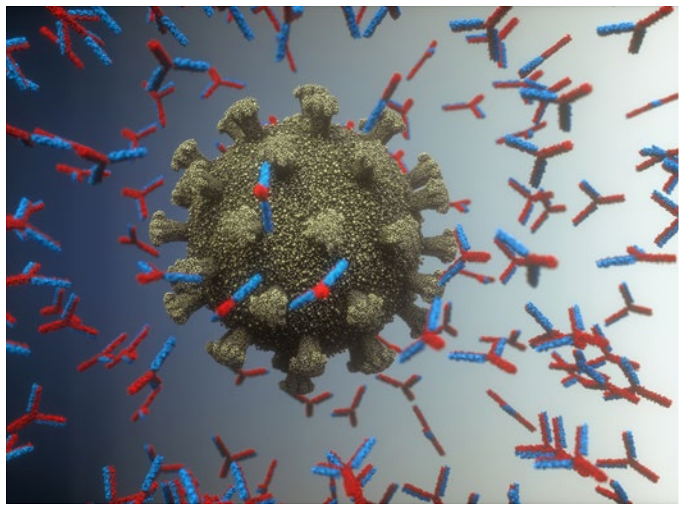


Figure 2.28: Antibodies attach to specific pathogens and stop them from harming the body until they can be destroyed by other immune cells such as phagocytes.

Figure 2.29: Vaccination introduces a non-harmful form of a specific pathogen into the body, allowing the adaptive immune system to remember it for future exposures.

Vaccinations help to prevent infectious disease

Vaccinations contain part of the pathogen responsible for the infectious disease. The pathogen is either a weaker form of the disease or dead, so it cannot spread throughout the body. When a person is injected with it or swallows it, their immune system acts to fight it off, with B lymphocytes producing antibodies and then memory cells. The person's body then usually 'remembers' the disease and becomes immune to it. If the person comes in contact with the disease again, they can remain healthy, as the adaptive immune response will immediately produce antibodies and **neutralise** the pathogen.

Edward Jenner created the first vaccination

The first vaccine was discovered and developed at the end of the 18th century by English doctor Edward Jenner. He lived at a time when smallpox was killing millions of people all around the world.

Jenner noticed that people who had been exposed to cowpox – a very similar but much less dangerous disease – were immune to smallpox. One day, he experimented on the eight-year-old son of his gardener. He rubbed pus from cowpox blisters into an open wound on the boy's arm. Jenner's experiment worked, and the boy became immune to smallpox.

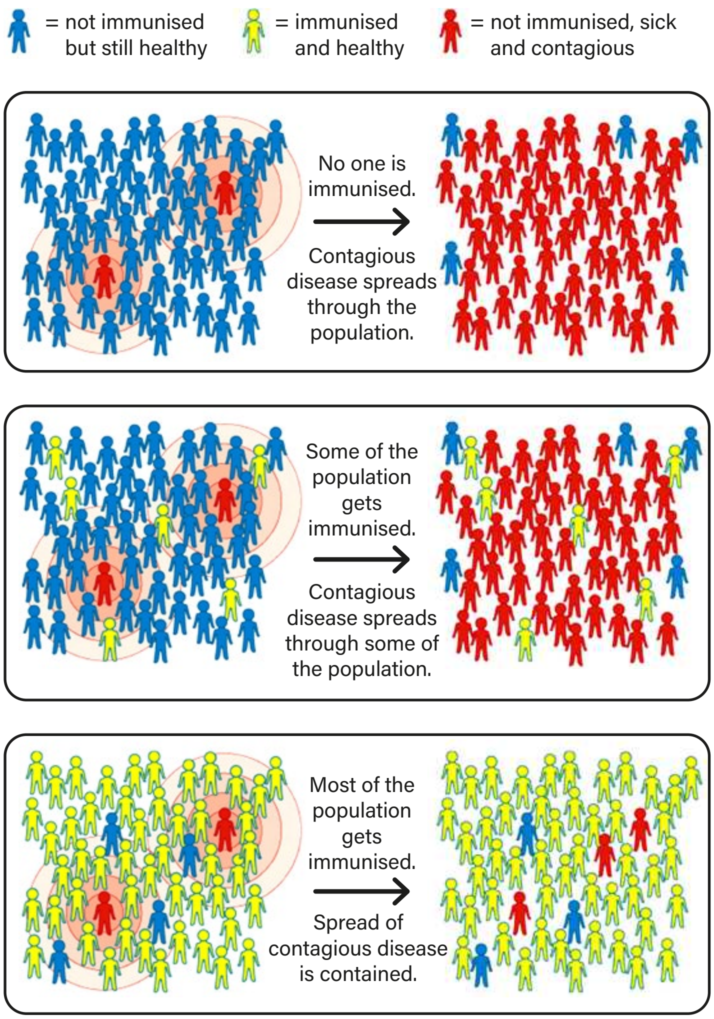


Figure 2.30: High rates of immunisation against specific pathogens can provide populations with herd immunity.

A high rate of vaccination in a population creates herd immunity

Sometimes people within a population cannot be vaccinated, for various reasons; for example, they may have an allergic reaction to them. These people are still protected against infection by a particular disease if most of their community has been vaccinated against that disease. This is called **herd immunity**. Herd immunity works because having large numbers of the population vaccinated means that there are not enough hosts for the disease to infect and spread throughout a population. This is how the disease smallpox was eradicated. For most diseases, 95 per cent of the population or higher need to be vaccinated to protect the remaining individuals who are unable to be vaccinated from the disease. Table 2.7 shows an example of this.

Table 2.7: The effectiveness of herd immunity across a population vaccinated against the measles virus (percentages are approximate)

Proportion of population vaccinated (%)	Susceptible individuals (%)	Risk of death from disease
0	100	High
50	50	Moderate
75	15	Low
90	5	Very low
95	<1	Negligible

Learning Ladder

Disease

1. Identify a disease that can be prevented by vaccination.
2. Describe how a vaccine works.
3. Explain the link between vaccinations and the adaptive immune system.
4. Consider Table 2.7. At what point does the risk of measles infection drop significantly?
5. Analyse the effectiveness of vaccination as a method of preventing infectious diseases.

Analysing data and information *see page 420*

1. Describe a trend from the data in Table 2.7.
2. Explain the relationship between vaccination rates and cases of a disease, using the infographic in Figure 2.30.
3. Draw a conclusion about vaccinations from the data and figures in this section.
4. Consider the data in Table 2.7 and its description. Is this data valid? Justify your decision with evidence.
5. Evaluate the conclusion you made in your response to Question 3.

In context

Vaccination can also be used to help prevent some non-infectious diseases. Find an example of a non-infectious disease whose incidence rate is reduced through vaccination and explain how vaccination reduces the risk of this disease.

Success criteria

- I can describe what a vaccination is.
- I can outline how a vaccination causes the body to produce antibodies that fight infection.

2.10 ▸ Controlling non-infectious diseases

Learning intention

At the end of this lesson, I will be able to describe a number of strategies that can help reduce the incidence of non-infectious diseases.

Key term

control: a method that can be used to prevent or treat a disease

Content group: Disease control and prevention

Non-infectious diseases can occur for several reasons. To try and reduce the incidence of non-infectious diseases, several strategies have been implemented in Australia. These strategies focus on public education, restricting disease-causing products and enabling access to health care.

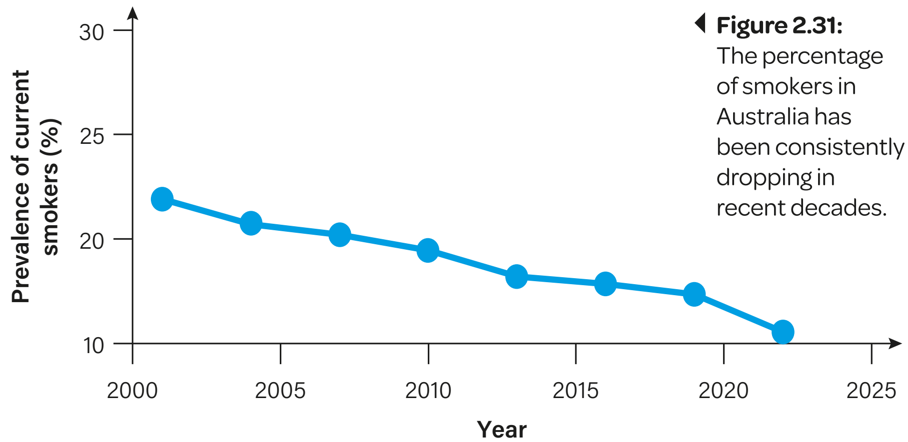


Figure 2.31: The percentage of smokers in Australia has been consistently dropping in recent decades.

Figure 2.32: In Australia, cigarette packets have large print warnings to clearly show the diseases and disorders cigarettes can cause.

Public education can increase awareness

Lung cancer is a non-infectious disease that has been consistently linked to cigarette smoking. Data from the Cancer Council suggests that about 90 per cent of lung cancer cases in males and 65 per cent of cases in females are linked to tobacco smoking. Since the 1970s, the Australian Government has been running public education campaigns to increase awareness of the risks of cigarette smoking (Table 2.8).

These campaigns help to increase awareness in order to reduce the incidence of smoking-related diseases such as lung cancer. Data across Australia shows that the percentage of the population who smoke has steadily declined (Figure 2.31).

Table 2.8: Public education campaigns to increase awareness of the risks of cigarette smoking

Campaign	Description
Plain Packaging	Cigarettes are packaged in plain packs that display graphic warnings of their health risks
National Tobacco Campaign	Targeted ads on television and social media to help people understand the risks of smoking
Never Give Up Giving Up	A New South Wales-based campaign that promotes the importance of continuing to try to quit smoking, even if the first attempt is not successful

Policies reduce access to disease-causing agents

A lot of the information in public education campaigns is controlled through specific policies and legislation. Several Australian laws aim to reduce the number of Australians who smoke.

- The *Tobacco Advertising Prohibition Act 1992* bans advertising of cigarettes and other tobacco products in Australia.
- The *Tobacco Plain Packaging Act 2011* requires all tobacco products sold in Australia to be placed in plain packaging.

- The *Competition and Consumer (Tobacco) Information Standard 2011* requires that all tobacco products sold must also display large text and graphic warnings about the danger of cigarettes.

Laws also limit where people can smoke. This reduces the risk of non-smoking individuals and people under the age of 18 from being exposed to second-hand cigarette smoke. People under 18 are also not allowed to purchase cigarettes, further reducing access to them.

Access to health care helps to diagnose and treat diseases

Diabetes is a major issue in Australia, with more than 1.7 million Australians suffering from some form of the disease. Diabetes affects the metabolism and is marked by high blood sugar levels. It can lead to cardiovascular disease, stroke, kidney disease, damage to the eyes and many other conditions.

Figure 2.33: Most people with diabetes need to regularly check their blood sugar level using a blood glucose meter.

Type 1 diabetes, where the pancreas no longer secretes insulin, can be treated with regular insulin injections. Type 2 diabetes is a lifestyle disease, where insulin is produced but the target cells do not react to it. It is linked to obesity, high sugar intake and lack of exercise.

Diabetes is a major focus of medical research. The Australian Foundation for Diabetes Research is currently developing a form of insulin graft – an artificial device that produces insulin in the body. The graft is a network of microscopic bubbles, created from seaweed, that are filled with insulin. Devices like this could revolutionise the treatment of type 1 diabetes. Type 2 diabetes is better treated with lifestyle changes through diet and exercise.

A part of the **control** of diabetes relies on access to health care. Regular visits to a doctor increase the chances of diabetes being diagnosed and managed.

Learning Ladder

Disease

1. Identify two strategies that can help to control the incidence of non-infectious diseases.
2. Describe how the two strategies you identified in Question 1 help manage the incidence of the disease.
3. Explain why access to a health-care provider can help in the diagnosis and treatment of non-infectious diseases.
4. Using Figure 2.31, calculate the approximate percentage reduction in smokers in Australia between 2001 and 2022.
5. Analyse the effectiveness of public education campaigns, based on the percentage of smokers in the Australian population between 2001 and 2022.

Analysing data and information *see page 420*

Consider the graph in Figure 2.31.

1. Describe the trend of the data.
2. Explain the relationship between the percentage of smokers in Australia and the number of Australians with lung cancer.
3. Draw a conclusion about what you would expect to see in terms of the number of Australians with lung cancer over the next 20 years, based on the trend you described in Question 1.
4. Assess the validity of the data shown in Figure 2.31.

In context

'Healthy Harold' is a campaign to educate young Australians about the importance of healthy eating behaviours, as well as the dangers of using cigarettes and drugs. Explain why a campaign like this is an effective way to reduce the incidence of non-infectious diseases in Australia.

Success criteria

- I can identify a number of causes of non-infectious diseases.
- I can describe a range of strategies that could help reduce the incidence of these non-infectious diseases.

2·11 ► Controlling infectious diseases

Learning intention

At the end of this lesson, I will be able to assess measures that can prevent the incidence and spread of infectious diseases.

Key terms

quarantine: separating and restricting the movement of people who have been exposed to an infectious disease to see if they become sick

social distancing: maintaining a distance from other people to avoid catching or transmitting an infectious disease

Content group: Disease control and prevention

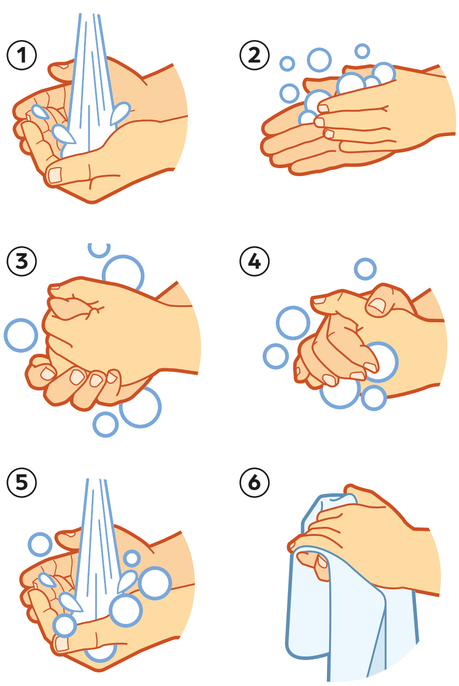


Figure 2.34: Washing your hands is one of the most important ways to maintain health and hygiene, not just for yourself but for everyone you come in contact with.

Infectious diseases can be controlled by not getting infected yourself, by not infecting others, and by seeking treatment if you do become infected.

Protective measures aim to slow the spread of COVID–19

Since 2019, COVID-19 has been spreading around the world. Public health campaigns, quarantine and medical treatments have all been used to try to reduce the number of cases.

Special protective measures included **social distancing** (staying at least 1.5 m apart from other people), coughing or sneezing into your elbow instead of your hand, using a contact tracking app like COVIDSafe, increased testing and frequent washing of hands (Figure 2.34).

Public health campaigns promote hygiene

Public health campaigns aim to inform people how to protect themselves and others from infectious diseases. World Hand Hygiene Day is a campaign developed by the World Health Organization to educate people about proper hand washing, and about how it can help to reduce the transmission of infectious pathogens by removing them from our bodies.

These campaigns are very effective and have reduced the incidence and transmission of disease both inside and outside of hospitals.

Quarantine prevents disease transmission

Quarantine measures can involve both healthy and sick individuals.

During an outbreak of an infectious disease, cases of the disease can be tracked. Anyone who has been exposed to the pathogen is required to quarantine, or stay home and away from others, for the incubation period of the disease. This is the time it takes for symptoms to develop. In this way, anyone who becomes sick after being exposed cannot infect others, which reduces the rate of transmission and the number of cases.

The secondary part of quarantine is isolation of sick people at home, or by themselves in a hospital, so that they cannot pass on the pathogen and infect other people.

Quarantine is highly effective at preventing the transmission of infectious diseases, but only if exposed and infected individuals stay away from others for the entire time they could potentially infect them.

Table 2.9: Some common medical treatments and their effectiveness

Treatment	Controls	Works by	Effectiveness
Antibiotics	Diseases caused by bacterial pathogens, such as cholera and tuberculosis	Killing the bacteria or preventing them from replicating, so the immune system can fight the disease	Very effective when used correctly. Incorrect use, such as not taking a full course of antibiotics, can lead to antibiotic-resistant bacteria, which need stronger antibiotics to be destroyed.
Antivirals	Diseases caused by viruses, such as influenza (the flu) and COVID-19	Preventing viruses from entering cells where they would be able to multiply and spread	Highly effective if given early. If taken later, the virus may be in too many body cells for antivirals to help.
Antifungals	Diseases caused by fungal pathogens, such as ringworm and tinea (athlete's foot)	Preventing the fungus from growing normally, so that the immune system can break it down and fight off the infection	Highly effective when used correctly. Like antibiotics, they must be used for a specific length of time, or the fungus can become resistant to the treatment.

Medical treatments help to treat and cure infectious diseases

Sometimes outbreaks of infectious diseases can occur, even with the use of preventative strategies. When outbreaks occur, medical treatment can reduce the severity of the infection and the chances of dying. This makes having access to doctors and hospitals very important. Table 2.9 shows some common treatments for diseases caused by pathogens. Treating infectious individuals also reduces the risk of the disease spreading.

▲ **Figure 2.35:** Social distancing was a crucial part of slowing the spread of COVID-19 in Australia.

Learning Ladder

Disease

1. Identify a strategy that helps to control a named infectious disease.
2. Describe how the strategy you identified in Question 1 helps to reduce the incidence and transmission of the disease.
3. Explain why it is important to know which type of pathogen is responsible for an infectious disease before treating it.
4. The incubation period of COVID-19 is 2–14 days. Explain how this might affect someone who needed to quarantine after being exposed to a person infected with COVID-19.
5. Assess the effectiveness of:
   a hand hygiene. **b** quarantine.
   c medical treatment.

Communicating

see page 429

1. Describe a way to communicate information about proper hand washing to a teenage audience.
2. Construct a visual infographic as part of the communication strategy you described in Question 1.
3. Construct a brief presentation explaining why prescribing antibiotics for the flu is an issue.
4. Discuss your presentation with a group of your peers. Use their feedback to describe two ways your presentation could be improved.
5. Conduct some secondary-sourced research into the use of antibiotics. Use your findings to evaluate the information you have included in your presentation from Question 3.

In context

Many infectious diseases require multiple control strategies. Identify an infectious disease and use secondary sources to research and explain it. Assess the effectiveness of each control strategy provided in this section, in relation to its ability to prevent the incidence and transmission of the disease.

Success criteria

- I can describe strategies that help prevent the incidence and spread of infectious diseases.
- I can assess the effectiveness of these strategies.

2.12 ▸ The use of bush medicine in controlling diseases

Learning intention

At the end of this lesson, I will be able to explain how some plants have been used as bush medicine.

Key terms

health: in First Nations health care, holistic wellbeing, including mental and social health

impersonal: without personal feelings; in health care, being treated like an illness rather than a person

Ngangkari: an Aboriginal healer who has extensive knowledge of bush medicine and the ceremonies and rituals required to achieve the best health outcomes

patent: a type of legal ownership of intellectual property that gives the owner the right to exclude others from making, using or selling an idea or invention

Content group: Disease control and prevention

Figure 2.36: The Australian desert mushroom was used to treat illnesses in the mouth and as a teething aid for infants.

Since before colonisation, Aboriginal and Torres Strait Islander Peoples have used various plants to make different types of bush medicine. These medicines were made from plants and were often traded over large distances to places where the plants could not be cultivated. Many plants are still used as bush medicine and many more are currently being researched.

Health is more than an absence of illness

For thousands of years, First Nations Peoples have practised health care by considering the wellbeing of the whole person. **Health** is understood to be not just an absence of illness but an overall feeling of wellness. This includes nutrition, exercise, and feelings of belonging and of having mental health support.

This means that First Nations Peoples practise medicine holistically, and treatments can include dance, movement, ritual and ceremony to support the physical, psychological and spiritual elements of a person. This contrasts with the sometimes **impersonal** experiences of medical treatment in a Western health-care system.

Medicinal plants are important in bush medicine

The use of plants is a central part of bush medicine. Knowledge of the plants has been passed down for generations to community healers and doctors. In the Anangu Pitjantjatjara Yankunytjatjar Lands of South Australia, these people are called **Ngangkari** healers. They often work with Western doctors and in Western hospitals to ensure that Aboriginal and Torres Strait Islander patients get appropriate treatment.

Many native plants have been used for medicinal purposes for thousands of years. For example, the oil of the tea tree (*Melaleuca alterifolia*) has been used by the Bundjalung People as an antiseptic to treat wounds and infections for thousands of years.

Another common plant used for bush medicine is *Eucalyptus globulus labill*. The oil from the eucalyptus tree is used to treat a variety of symptoms, including body pains, fevers and chills, and many different throat and lung illnesses. It is a common ingredient in many mouthwashes, throat lozenges and cough suppressants.

Sometimes multiple plants have been used at the same time to treat more complex illnesses. For example, the sandpaper fig (*Ficus opposita*) (Figure 2.37) and the stinking passion flower (*Passiflora foetida*) were often used together in northern coastal communities to help people with itchy skin. The fig leaves were crushed and soaked in water and then

Figure 2.37: A leaf of a sandpaper fig. First Nations Peoples rubbed the abrasive leaves of this plant on the skin until it bled, when other bush medicines could be applied to the wound.

rubbed on the skin until it bled. The passion flowers were then smeared onto the affected area to provide relief. Sandpaper fig leaves have also been used to treat fungal skin infections such as ringworm and sometimes in combination with the fig's milky sap.

Fungi are also part of bush medicine

Many fungi also provided important medicine for Aboriginal and Torres Strait Islander Peoples. For example, the desert mushroom (*Pycnoporus coccineus*) (Figure 2.36) has been used to treat pain in the mouth related to ulcers and sores, and as a teething aid for infants and for babies suffering from oral thrush.

Patenting Indigenous medicine restricts their access to it

In many ways, Western medicine is only now beginning to catch up to First Nations medical knowledge. This has created opportunities to find new drugs to help treat illnesses. However, once these drugs are isolated in the laboratory, they are often **patented** as belonging to the medical research companies that 'discovered' them. This is a growing problem for many First Nations healers, who are sometimes forbidden from accessing, or are forced to pay large sums of money to access, plants that have been keeping people healthy for thousands of years.

Learning Ladder

Disease

1. Identify the definition of health that First Nations Peoples use.
2. Describe how Aboriginal and Torres Strait Islander Peoples have used three named plants to help manage disease.
3. Explain the uses of the oil from the tea tree.
4. Propose why First Nations Peoples sometimes treat illnesses using multiple plants.

Communicating

see page 429

1. Describe ways to communicate with doctors about how they may use eucalyptus oil in treatments, and outline the key information a doctor would need to know.
2. Use a digital spreadsheet to list the plants and fungi mentioned in this section and their uses in treating illnesses. Compare their similarities and differences.
3. Construct a poster outlining the stages of using sandpaper fig and stinking passion flower to treat a skin irritation.
4. Swap your poster with a peer, and provide two pieces of feedback: one feature you liked about their poster, and one thing you wish you had seen.
5. Conduct research into tea tree oil and its qualities as an antiseptic. Discuss why so many products contain this oil.

In context

Kakadu plums are a native plant with many uses for First Nations Peoples. A US company tried to patent this plant to use in its cosmetics, due to the plums' high levels of vitamin C. Analyse the impact of patents like this on the intellectual property of First Nations Peoples.

Success criteria

- I can explain how some plants are used as bush medicine.
- I can describe how Aboriginal and Torres Strait Islander Peoples' medicine is holistic.

2.13 ▸ Immunisation programs

Learning intention

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

- describe the importance of immunisation programs
- analyse data relating to immunisation programs to identify patterns linked to disease occurrence.

Key term

immunisation program: a series of vaccinations given to individuals to help prevent specific infectious diseases in populations

Investigation 2.13

Infectious diseases and vaccination: data analysis, page 498

Content group: Disease control and prevention

Vaccinations protect us from a range of infectious and non–infectious diseases. To stay protected, there are specific vaccination schedules that are used to show us what we should be vaccinated against and when.

Australia has specific vaccination schedules

Australia's National Immunisation Program was established in 1997 by the Australian Government's Department of Health. The **immunisation program** is a funded schedule of recommended vaccinations against a number of diseases across a person's life span.

Immunisation programs target specific diseases

The vaccinations set out in the National Immunisation Program target a range of specific infectious and non-infectious diseases. This helps to provide the community with herd immunity from these diseases, by getting vaccination rates to 95 per cent or above. High vaccination rates prevent infectious diseases from spreading through communities. Table 2.10 sets out information on the diseases covered in the National Immunisation Program and when they are administered. Diseases with multiple rounds of vaccination require multiple exposures for our adaptive immune system to produce a high enough level of antibodies to give us lasting immunity.

Table 2.10: Diseases covered in Australia's National Immunisation Program – vaccinations available to all individuals

Disease	Age of vaccination(s)	Disease	Age of vaccination(s)
Hepatitis B	Birth, 2 months, 4 months, 6 months	Influenza	6 months, 1.5 years, 2.5 years, 3.5 years, 4.5 years, ≥65 years
Diphtheria	2 months, 4 months, 6 months, 1.5 years, 4 years, 12 years	Meningococcal	1 year, 16 years
Tetanus	2 months, 4 months, 6 months, 1.5 years, 4 years, 12 years	Measles	1 year, 1.5 years
Pertussis (whooping cough)	2 months, 4 months, 6 months, 1.5 years, 4 years, 12 years	Mumps	1 year, 1.5 years
Haemophilus influenzae type b (Hib)	2 months, 4 months, 6 months, 1.5 years	Rubella	1 year, 1.5 years
Polio	2 months, 4 months, 6 months, 4 years	Varicella (chickenpox)	1.5 years
Rotavirus	2 months, 4 months	Human papillomavirus (HPV)	12 years
Pneumococcal	2 months, 4 months, 1 year	Shingles	≥65 years

Vaccination is reducing the impact of diseases

A 2019 study by the Australian Institute of Health and Welfare suggests that vaccinations are having a positive effect against vaccine-preventable diseases. The study focused on the impact of these diseases on the Australian health-care system.

Data from the study indicates that the impact of vaccine-preventable diseases decreased by 31 per cent between 2005 and 2015. This supports the idea that vaccinations help to reduce the incidence and severity of diseases. Additionally, clear correlations can be seen between vaccination for varicella virus (chickenpox) and the number of deaths. Since the vaccine's introduction in 2005, hospitalisations for people aged 0–14 years with chickenpox have been significantly reduced. This can be seen in the graph in Figure 2.38. Trends like this are common for many diseases included within the vaccination schedule.

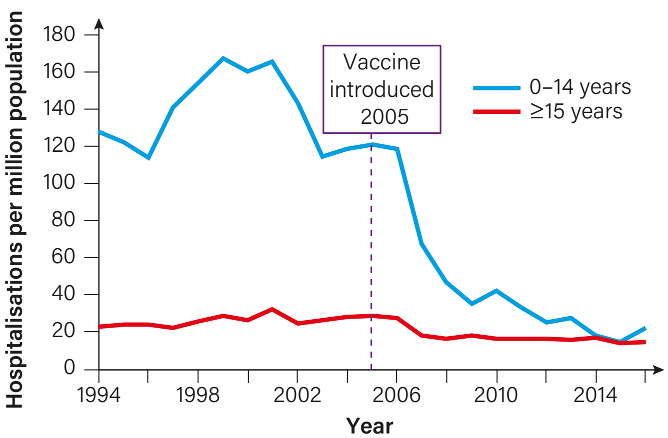


Figure 2.38: The introduction of the varicella (chickenpox) vaccine in Australia in 2005 significantly reduced the impact of the disease in young Australians.

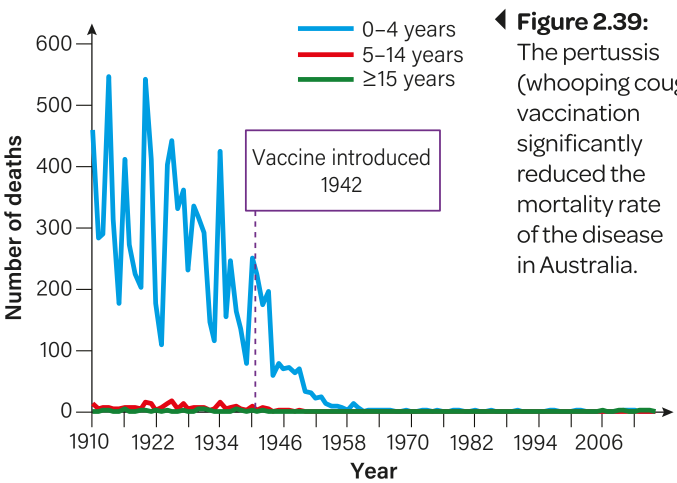


Figure 2.39: The pertussis (whooping cough) vaccination significantly reduced the mortality rate of the disease in Australia.

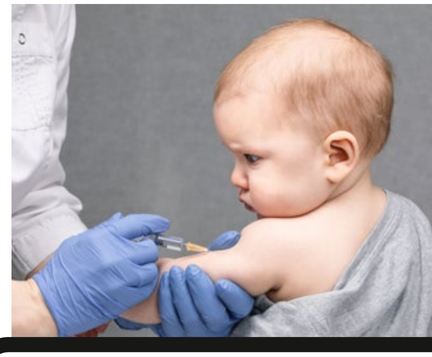


Figure 2.40: Vaccination schedules help to protect us from several diseases from when we are born.

Learning Ladder

Disease

1. Identify three diseases that are covered in the National Immunisation Program.
2. Describe how a vaccination schedule can help to reduce the severity of diseases.
3. Explain why it is important to get vaccinated against a named disease.
4. Describe three diseases that require multiple exposures to develop immunity, based on the data in Table 2.10.
5. Analyse the effectiveness of the varicella (chickenpox) vaccine in Australia.

Analysing data and information

see page 420

1. Describe the trends in the graphs in Figures 2.38 and 2.39.
2. Explain the relationship between the data in Figure 2.39 and the introduction of the pertussis (whooping cough) vaccine.
3. Draw a conclusion about the use of the varicella (chickenpox) vaccine, based on the data in Figure 2.38.
4. Using secondary research, assess the reliability of the data in Table 2.10.
5. 'Vaccination is the most effective mechanism of controlling diseases in Australia.' Evaluate this conclusion based on the information in this section on infectious diseases.

In context

Select another disease that is covered in the National Immunisation Program. Using data from the Australian Institute of Health and Welfare website, analyse the impact of the vaccine on the rates of hospitalisation and death for your chosen disease.

Success criteria

- I can describe a named immunisation program.
- I can analyse data on the immunisation program for trends and link this data to disease occurrence.

2·14 ▸ Disease in context

Learning intention

At the end of this lesson, I will be able to explain several Australian technological advances that have improved our ability to treat and manage a range of diseases.

Key term

technological advances: making improvements to existing ideas in order to find new solutions to problems

Content group: Disease in context

Over time as technology advances, scientists can develop more effective ways to treat and manage diseases and disorders. Australian scientists have played a crucial role in the development of many of these technologies and continue to work on new management options.

Spray–on skin helps to treat burns

Professor Fiona Wood is an Australian scientist who has lived and worked in Western Australia since the 1980s. To improve patient survival rates from post-surgery infections, Professor Wood investigated new methods of repairing the skin of people who had suffered burns. Her technology – ‘spray-on skin’ – was developed and tested throughout the 1990s and was first used to treat victims of the Bali bombings in 2002. This technology allowed skin cells to be ‘sprayed’ onto burn sites and reduced the time it took for cells to graft from 21 days to just 5 days. This technology is now used worldwide and reduces healing time, scarring and infection rates in burns victims.

Figure 2.41: Professor Fiona Wood developed ‘spray-on skin’, a way of introducing skin cells to burns that significantly improved the application of skin grafts.

The bionic eye aims to help with vision disorders

The idea of a bionic eye has existed for decades, but this specific technology is yet be commercialised. Researchers from Monash Vision Group are actively working to change this and have developed and tested a bionic eye prototype.

The bionic eye is designed for individuals with retinitis pigmentosa and macular degeneration – disorders that affect the retina of the eye. An electrode is placed behind the eye through surgery and is connected to a video camera in a pair of glasses. When the camera is pointed at images, it sends signals to the electrode, which communicates with the retina, helping people to see.

In a 2018 clinical trial, the implant was given to four patients with retinitis pigmentosa. These patients were tracked from implantation until 2021. Findings from the study show that the patients were able to see ‘edges, shapes and movement’ using the device. More research, developments and studies will be conducted into improved models of the bionic eye, and it is hoped that one day it will be used to assist people with a range of vision conditions.

Figure 2.42: A prototype of the bionic eye, a technology that is being developed to reduce the impacts of vision loss.

New research and processes continue to help technology development

Professor Fiona Stanley is another Australian scientist who pioneered research that helps to manage diseases. Professor Stanley focused her research on birth defects in children – specifically, neural tube defects, or problems with the brain and spinal cord. One example of this is spina bifida, where the spinal cord does not develop properly, which can result in part of the spine protruding from the back. In 1989, Professor Stanley's team discovered that if mothers consumed the nutrient folate during pregnancy, this could significantly reduce the risk of neural defects in their babies.

Figure 2.43: Professor Stanley's work has helped to significantly reduce rates of neural defects such as spina bifida.

In 1990, Professor Stanley founded the Telethon Kids Institute. Continued research into the link between folate and neural defects in newborns through the Telethon Kids Institute led to the Australian Government introducing requirements to enrich bread with folate in 2007. To this day, the Telethon Kids Institute and many scientists continue to research neural tube defects, their causes and potential prevention methods and cures, in order to make **technological advances** to help affected children and their families.

Learning Ladder

Disease

1. Identify two disorders that have been assisted by technological developments.
2. For each disorder, describe how a specific technology can help to manage or cure the condition.
3. Explain why continued research into technologies is useful when managing diseases and disorders.
4. Explain the impact of folate on an unborn child.
5. Analyse the effectiveness of spray-on skin for treating burns.

Communicating

see page 429

1. Describe a way you could communicate information to your peers about the impact of a technology discussed in this section.
2. Construct a digital poster about the bionic eye, including what disorders it could help to manage, and how it does this.
3. Write a scientific article on the development of spray-on skin, which explains when and how it is used to treat patients. Use secondary sources as needed.
4. Present your article from Question 3 to a group of students in your class and provide two pieces of feedback on another student's article.
5. Evaluate the importance of research into new technologies in relation to the management of diseases. Why should funding be given to projects like spray-on skin, the bionic eye and neural defect research?

Success criteria

- I can identify and described a named technology that assists in the diagnosis or treatment of a disease.
- I can explain how this technology has improved our ability to diagnose or treat or manage a specific disease.

Disease summary

Homeostasis

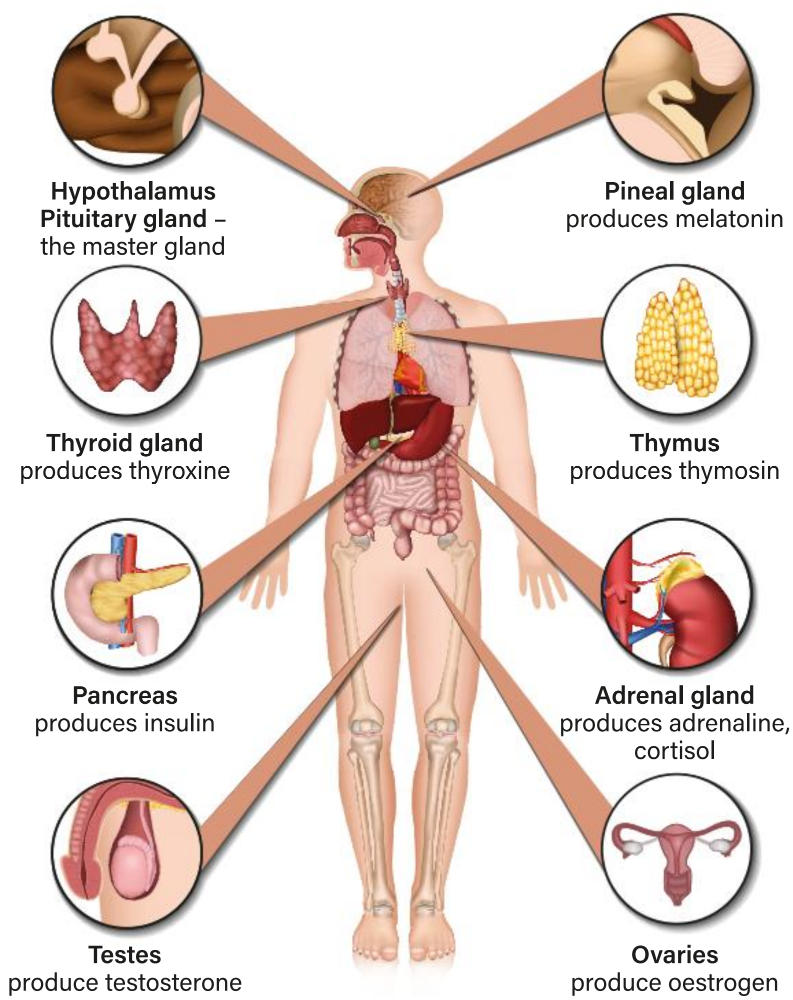
- Homeostasis is the baseline, stable state when the body's internal environment (i.e. its organs, systems and processes) is working efficiently.
- The body maintains a balanced internal environment by detecting and responding to external changes such as changes in temperature and glucose levels.
- Receptors in the body detect changes from the baseline and send messages to effectors via feedback loops.
- Negative feedback loops counteract stimuli (e.g. by regulating temperature to prevent heat loss).
- Positive feedback loops amplify stimuli (e.g. by increasing labour contractions to stimulate birth).
- Effectors carry out actions to return the body to homeostasis.

Stimulus
Body temperature is reduced to below 37 °C.

Sensor
Nerve cells (neurons) in the skin detect the change.

Control centre
The brain receives the message and triggers a response.

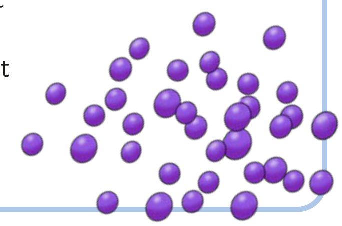
Effector(s)
Shivering, goosebumps and vasoconstriction.



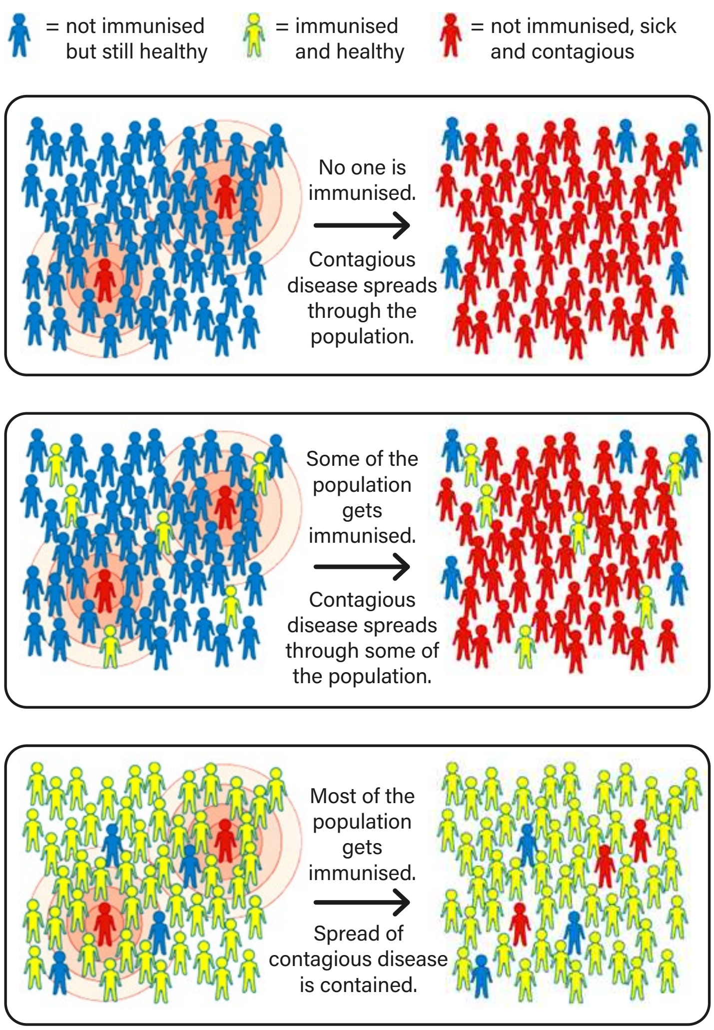
- The nervous system is made up of the central nervous system (brain and spinal cord) and the peripheral nervous system (network of nerves).
- The nervous system transmits signals around the body, using neurons, the brain and the spinal cord, to coordinate conscious (e.g. voluntary movement) and subconscious (e.g. involuntary breathing) processes.
- The endocrine system releases hormones from glands to help us respond to stimuli and to control bodily processes (e.g. insulin helps to control our blood glucose levels).
- The nervous and endocrine systems work together to coordinate the body's responses to changes in its internal and external environments.
- The brain plays a large part in both systems.
- The hypothalamus, in the centre of the brain, interprets signals from all over the body to ensure homeostasis.

Infectious and non-infectious diseases

- Infectious diseases are caused by pathogens and can be transmitted by direct contact, indirect contact and vectors such as insects.
- Non-infectious diseases cannot be transmitted between individuals and are caused by genetics, environmental conditions and nutrition.
- Infectious diseases can spread across a localised region (epidemic), occur consistently within a specific area (endemic), or become globally widespread (pandemic).
- Heart disease is a common non-infectious disease. It is one of the highest causes of mortality for Australians each year.
- The immune system has three lines of defence to help protect us from infectious diseases.
  - Physical and chemical barriers block pathogen entry.
  - Phagocytes (a type of white blood cell) engulf and destroy foreign materials.
  - Lymphocytes recognise, remember and kill specific pathogens that we have previously been exposed to.
- Vaccination helps to prevent diseases by allowing us to produce antibodies that fight the introduced pathogens, giving us immunity to specific diseases.



Disease control and prevention



- Public health campaigns can reduce the spread of non-infectious diseases by educating the public about the benefits of making healthy lifestyle choices.
- The spread of infectious diseases can be reduced by educating the public on hygiene and quarantine measures, which can reduce disease transmission and incidence.
- First Nations Peoples, such as the Bundjalung People, have long used natural products for medicinal purposes and to help control disease (e.g. oil from the tea tree plant is used as an antiseptic).
- In Australia, vaccination schedules help to protect us from diseases such as chicken-pox, whooping cough, and even certain forms of cervical cancer, by reducing their incidence.
- High rates of immunisation against specific pathogens can provide populations with herd immunity.

Disease in context

Technological advances such as spray-on skin and the bionic eye continue to improve our ability to understand and treat diseases and disorders.

Masterclass

Steps in progression

		1	2
Content	Disease	Identify the third- and fourth-highest causes of death in Australia in 2023.	Describe the category of disease that heart disease falls under and identify three contributing factors to heart disease.
Processes	Analysing data and information	Describe any trends you can see in Figure 2.45.	Explain the relationship between the diseases in Figure 2.45 and the likelihood of transmission to other individuals.
Processes	Communicating	You want to present the information on disease mortality rates to a group of Year 7 students. Describe an appropriate way to communicate this information.	Using a device, construct a digital table that represents the information in Figure 2.45 on mortality rates.

Australian mortality: what is leading the way?

Diseases are by far the leading cause of death in Australia, according to the Australian Bureau of Statistics. In 2023, Australia recorded 181 131 deaths. This might sound like a lot, but it was actually a 4.1 per cent reduction compared to the previous year. Data scientists have suggested that this is because of the increased protection and strategies surrounding the prevention of COVID-19, which ranked ninth on the 2023 list, causing just over 5000 deaths.

The six top mortality rates accounted for over one-third of all deaths in Australia for 2023. They are shown in Figure 2.45. How can we use this information to help reduce the annual mortality rate of Australians?

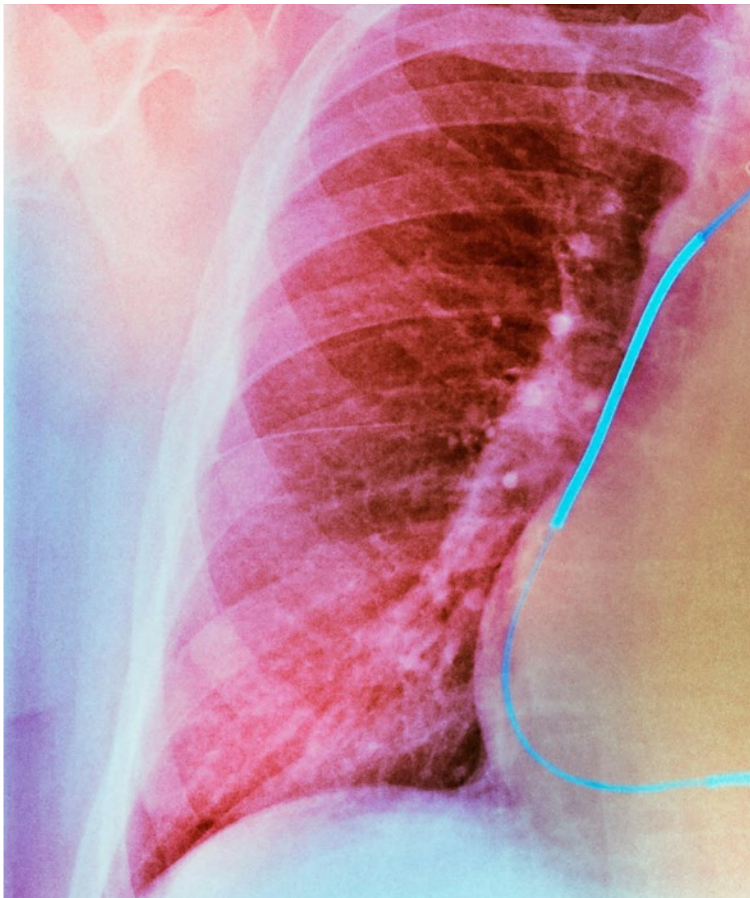
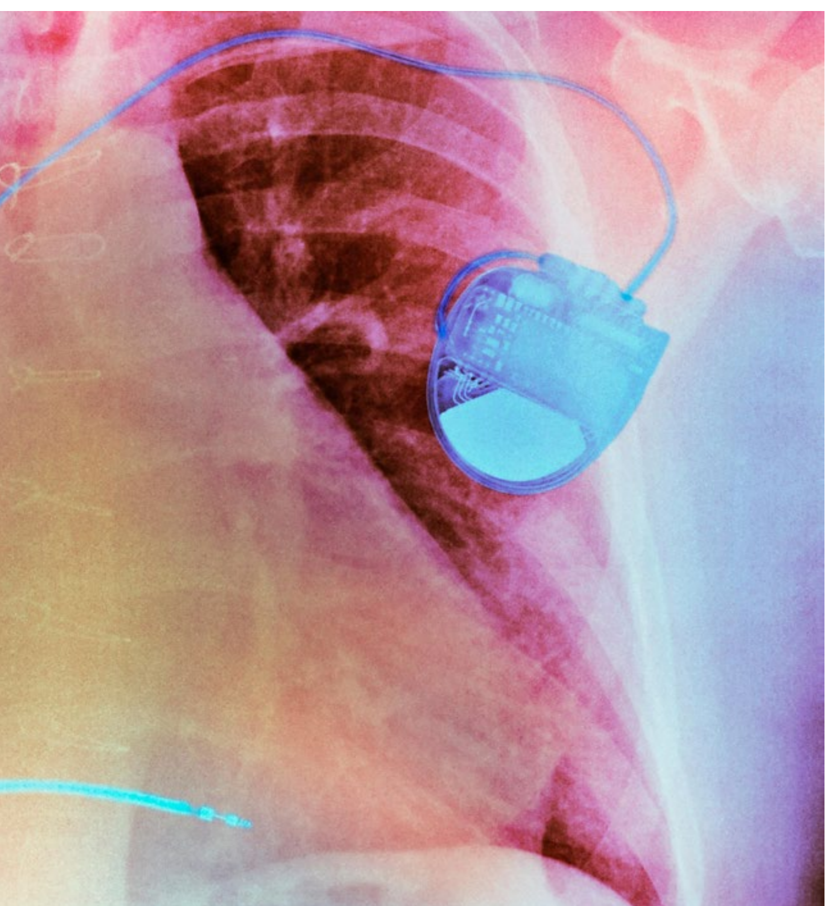


Figure 2.44: Technologies such as pacemakers are helping to reduce the number of individuals who die from heart disease.

Demonstrate your understanding

3	4	5	
Use secondary research to explain how improved prevention methods for COVID-19 have reduced Australia's mortality rates for the disease.	Using Figure 2.45, state the number of deaths caused by heart disease and by dementia in 2023, and calculate the percentage of total deaths they accounted for. Use pages 452–55 in the Science how-to section to help you if needed.	Use secondary research to identify two disease-prevention strategies for any two of the diseases presented in Figure 2.45. For each strategy, describe how it is implemented and analyse its effectiveness as a disease-prevention measure.	
Construct a conclusion about the link between mortality in Australia and non-infectious diseases.	The data provided in these pages is from the Australian Bureau of Statistics (ABS) website. Use the CRAAP test (see the Science how-to section on page 441) to assess the accuracy, reliability and validity of the data.	Use your assessment from step 4 to evaluate the quality of the conclusion you made in step 3.	Science how-to p. 420
Construct a digital scientific presentation, based on your description in step 1, that you could present to Year 7 students. Make sure to include at least five scientific terms. Break them down for the students, so that they understand them.	Deliver your presentation to a group of your peers in class and listen to their presentation. Describe three ways the other groups could improve their presentations.	Research secondary sources to obtain the mortality rates of five infectious diseases of your choosing, to add to your presentation. Evaluate the quality of the data in your presentation, based on your chosen sources and your assessment of the ABS website in your answer to step 4 of 'Analysing data and information'.	Science how-to p. 429



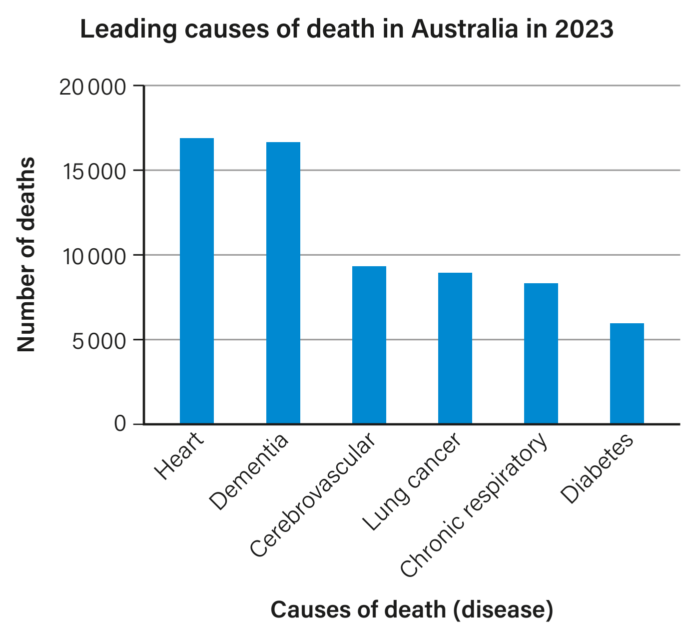


Figure 2.45: The leading causes of death by disease in Australia, 2023. The diseases shown are the six highest causes of death.

Focus area 3

3.0 Materials

Materials are the chemical substances that include everything around us, from the clothes we wear to the gadgets we use and even what we eat. Understanding materials involves exploring how resources are sourced and used, as well as the types of chemical bonds that connect atoms to one another. Carbon-containing materials, or organic compounds, are important both for their properties and for the reactions they undergo.

Figure 3.1: Different materials can be used in a variety of ways, depending on their properties and purpose.

Learning Ladder

The Learning Ladder contains the scientific content and processes you will learn in this focus area. Each area has five levels of progression. To move to higher levels, you need to practise activities at the earlier levels. This will help you develop the ability to complete tasks that are more complex.

Steps in progression	Materials	Planning investigations	Problem-solving	Communicating
5	I can evaluate how materials are sourced, used and modified.	I can assess the type of data that can be collected in a range of investigations.	I can evaluate scientific claims based on evidence.	I can evaluate scientific findings based on secondary evidence and arguments.
4	I can discuss the impact of various materials on the environment.	I can produce plans for investigations that are ethical, reliable and valid.	I can assess problem-solving strategies used to solve an identified problem.	I can present scientific findings using appropriate conventions for specific audiences.
3	I can explain the uses of materials based on their properties.	I can develop appropriate scientific aims for a range of investigations.	I can use given criteria to find solutions to scientific problems.	I can construct a range of appropriate scientific presentations based on first-hand and second-hand data and information.
2	I can describe materials based on bonding and properties.	I can distinguish between controlled, dependent and independent variables.	I can explain scientific problems and phenomena using cause-and-effect relationships.	I can use digital technologies to organise and present data and information.
1	I can classify different types of materials.	I can describe ways to reduce risks for a range of investigations.	I can propose solutions to familiar scientific problems.	I can select appropriate ways to communicate information.
	Content	Working scientifically processes		

Figure 3.2: Raw materials are extracted from the earth and undergo multiple changes before they become the familiar materials you encounter each day.

3·1 ▸ What is a resource?

Learning intention

At the end of this lesson, I will be able to identify and discuss different types of resources.

Key terms

crude oil: a naturally occurring liquid fossil fuel that can be refined to produce many different chemicals

finite: limited in size or amount

fossil fuel: an energy source made of ancient fossils

made resource: a resource that is manufactured from natural resources

natural resource: a resource that is useful in its natural form

non-renewable: finite, and will run out

renewable: can be renewed, and will not run out

resource: a source of something that is useful

Investigation 3.1

Investigating classroom resources, page 499

Content group: Resources

All the materials in the world start as a resource. Anything that a person can use is a resource. Some resources, such as vegetables, water and wool, do not need to be changed much or at all before we can use them. Other resources are processed to become more useful, and very different from how they started. These are new materials, such as plastic, concrete and some fabrics.

Resources can be renewable or non-renewable

Some **resources** replenish over time. The length of time this takes depends on the type of resource. A **renewable** resource can be infinite (never run out), such as wind or sunlight, or replenish itself within the average human life span (about 80 years). Crops are renewable because they can grow back within a relatively short time frame.

A **non-renewable** resource is **finite** (can run out) or can only be replenished over a much longer period than a human life span. **Fossil fuels** such as coal, oil and gas are non-renewable resources. Coal (the compressed remains of ancient plants) takes hundreds of millions of years to form, and it only forms under certain conditions.

Some trees can grow back in a life span, but some are many hundreds of years old. This means that trees can be renewable or non-renewable, depending on the type.

Figure 3.3: Cotton is a natural resource used as a fibre material in clothing and fabrics.

Figure 3.4: Tree trunks are a resource for timber.

Resources are often useful in their natural form

Natural resources are raw materials and sources of energy that are often useful in their naturally occurring form – we do not need to change them into something different before we use them.

Cotton is a common natural resource because the fibre material is not changed much from when it is picked in the fields to when it is used to make fabrics – it is still the same material. Wood is also a natural resource, which comes from trees and is cut into timber used in the building industry.

Figure 3.5: Concrete is a material made from a mixture of resources.

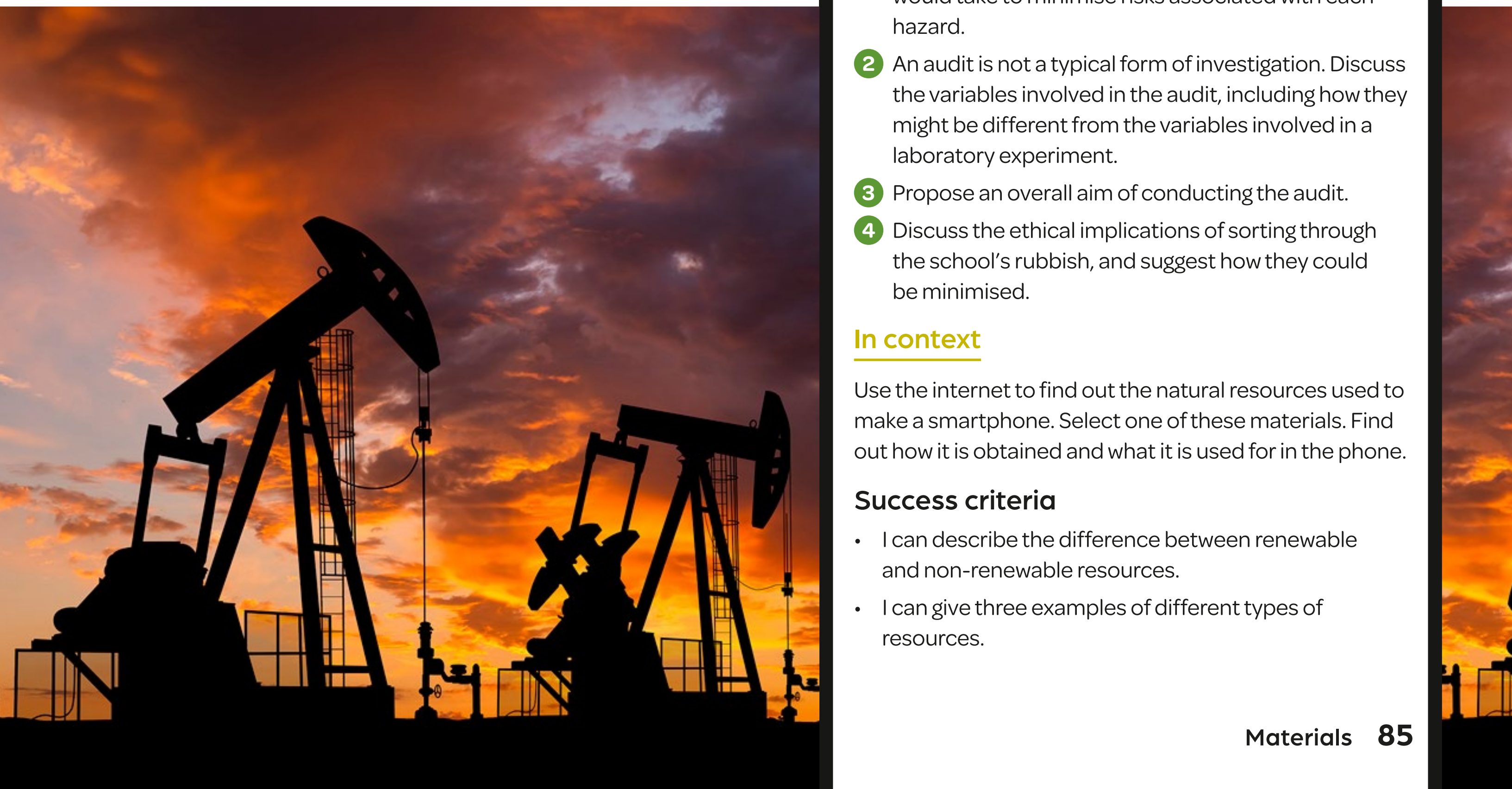
Figure 3.6: Plastic is a made resource used to manufacture a variety of products used every day.

Resources can be used to make new materials

Not every resource can be used without changing it. **Made resources** are new materials manufactured from natural resources and are often very different from the original resource.

Modifying and processing natural resources produces a huge variety of materials. Plastic packaging and polyester fabrics are made from **crude oil** extracted from the ground. Medicines are made from many different natural resources. Steel is made by mixing iron metal with carbon and other substances. Another term for made resource is 'synthetic resource'.

Figure 3.7: Crude oil is pumped from the ground and processed to form a variety of new resources.



Learning Ladder

Materials

1. **a** List three examples of natural resources and three examples of made resources.
   b List three examples of renewable resources and three examples of non-renewable resources.
2. Copy and complete the following sentences.
   A ________ is something that societies use in everyday life. A __________ resource can be restored within a life span. A non-renewable __________ is finite or takes much ________ to restore.
3. Explain how the examples you provided in Question 1 are used, based on their characteristics.

Planning investigations

see page 405

Imagine you are conducting an audit of the types of resources in the school's landfill skip.

1. Identify any hazards, and describe the steps you would take to minimise risks associated with each hazard.
2. An audit is not a typical form of investigation. Discuss the variables involved in the audit, including how they might be different from the variables involved in a laboratory experiment.
3. Propose an overall aim of conducting the audit.
4. Discuss the ethical implications of sorting through the school's rubbish, and suggest how they could be minimised.

In context

Use the internet to find out the natural resources used to make a smartphone. Select one of these materials. Find out how it is obtained and what it is used for in the phone.

Success criteria

- I can describe the difference between renewable and non-renewable resources.
- I can give three examples of different types of resources.

3·2 ▸ How have First Nations Peoples used minerals?

Learning intention

At the end of this lesson, I will be able to understand the different uses for hard and soft minerals by First Nations Peoples.

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

iron oxide: a dark red solid that exists as the mineral haematite and is the main component of rust

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

Content group: Resources

Figure 3.8: 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.

Minerals have been a valuable source of material for First Nations Peoples to make tools, as well as pigments, paints and dyes for decoration, for recording stories and for ceremonial purposes.

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 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.

The axes were used 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 resharpening. 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.

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 wood – objects, or animal skins, and are also commonly used as body paint for ceremonial purposes. Often, there are restrictions

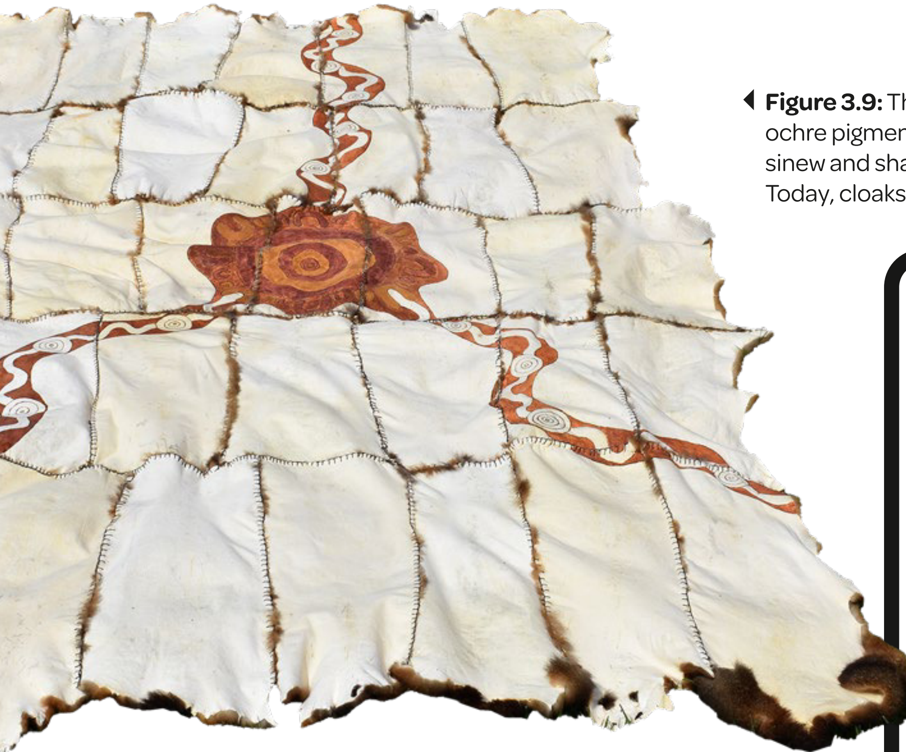


Figure 3.9: This possum skin has been decorated with paints made from ochre pigment, water and black wattle sap. Originally, possum or kangaroo sinew and sharpened possum bones were used to sew the pelts together. Today, cloaks are sewn using waxed nylon thread and metal gloving needles.

as to who is allowed to work with certain colours of ochre, who can wear the colours, 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 3.10: 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

Materials

1. Identify the properties of greenstone that make it a valuable material to use as an axe head.
2. Describe how ochre is bound to animal skin, using other materials.
3. Explain how the percentage of iron oxide in ochre might alter the way it is used.
4. Discuss how using a thermoplastic resin to bond the greenstone axe head to the wooden haft makes the axe more sustainable.

Problem-solving

see page 425

1. Observe the image in Figure 3.9. How do the materials used in the creation of a possum skin cloak support sustainable use of resources?
2. Explain how black wattle sap solves the problem of painting on animal skin with ochre.
3. Compare the characteristics of greenstone and ochre, and explain why greenstone is a more suitable material for constructing axe heads.
4. Images painted on animal skins with ochre often need to be repainted regularly due to deterioration. Identify a strategy to solve this problem and assess its effectiveness.
5. Evaluate the following claim: ‘Greenstone never had any value or useful characteristics.’ Use scientific evidence to justify your response.

In context

Conduct research into the term ‘thermoplastic’. Explain how the production and uses of this material have changed in Australia since colonisation. Construct a list comparing the production techniques and uses of this material.

Success criteria

- I understand that First Nations Peoples have used scientific reasoning to ensure that materials with favourable characteristics have been used to create appropriate tools.
- I can consider how First Nations Peoples have often used multiple materials at the same time to create tools and art, and as part of ceremony for millennia.

3.3 ▸ Mining Australian resources

Learning intention

At the end of this lesson, I will be able to identify and discuss some resources mined in Australia.

Key terms

metal ore: a metallic mineral deposit that is profitable to mine

mineral deposit: rocks that contain a particular mineral in large amounts

mineral reserves: parts of a mineral resource that can be mined economically

smelt: to extract metal from ore by heating and melting

Investigation 3.3

Making and mining 'ore', page 500

Content group: Resources

Australia has a wealth of minerals, from fossil fuels and metallic oxides to rare earth elements, and is one of the world's leading mining nations.

Fossil fuels include coal, oil and gas

Fossil fuels such as coal, crude oil and natural gas are produced from the remains of ancient plants and animals over hundreds of millions of years. Although fossil fuels are still being formed, they are being removed and used much faster than they are being restored.

Coal is formed from the remains of ancient swamps. This plant matter builds up over time and does not decay. As the plant matter is buried, heated and squashed under tonnes of soil, the water and impurities are squeezed out and it slowly changes into coal. Australia is one of the world's top producers of coal, which is a key resource for electricity generation (see Section 1.4).

Rocks and minerals provide metals

Rocks and minerals are finite, non-renewable resources because there are only limited amounts close to Earth's surface that we can access. Rocks are useful resources as building materials. They can be cut to make building stone or crushed to add strength to roads and concrete. Rocks contain minerals that include useful metals such as iron, lithium and aluminium. The minerals are known as **metal ores**, and in large amounts they are called **mineral deposits**. Mining and extraction processes remove and purify metals from their ores for use in manufacturing many items.

Table 3.1: Common metals mined in Australia

Metal	Mineral ore(s)	Location	Most useful property	Material use
Iron	Haematite, magnetite	Western Australia	Strong	Steel
Lithium	Spodumene	Western Australia	Durable, resistant to temperature changes	Lithium-ion batteries
Aluminium	Bauxite	Queensland, Northern Territory, Western Australia	Lightweight	Drink cans, aircraft
Copper	Chalcopyrite	Queensland, South Australia, New South Wales, Western Australia	Good conductor of electricity	Electrical wiring, computers, coins
Zinc	Sphalerite	Queensland, New South Wales, Northern Territory, Tasmania, Western Australia	Resistant to corrosion, blocks UV rays	Galvanising steel, sun screen

Iron ore is a vital mineral resource in Australia (Table 3.1). Pure iron is extracted from the ore and processed to produce steel. Steel is used to construct buildings, bridges and infrastructure, automobiles and machinery, household appliances and tools.

▲ **Figure 3.11:** An aerial view of Bulga Coal Mine, near Broke in the Upper Hunter Valley in New South Wales

Almost half of the world's lithium is mined in Australia. Lithium is a crucial component of batteries, especially lithium-ion batteries, which power electric vehicles, portable electronic devices, and energy storage systems. The demand for lithium continues to grow as technology advances and the shift to sustainable energy solutions accelerates.

Bauxite is one of Australia's most abundant **mineral reserves**. It consists of many metallic minerals, including aluminium oxide. Bauxite is refined into alumina, which is then **smelted** (processed by heating and melting) to extract aluminium, a lightweight and versatile metal. Aluminium is used in window frames, roofing, drink cans, aircraft and automotive parts. Its strength, durability and resistance to corrosion make aluminium indispensable in the manufacturing and construction industries.

▲ **Figure 3.12:** Iron ore looks very different from the iron metal that is extracted and used to make steel.

Learning Ladder

Materials

1. Classify the following resources as pure metal or mineral ore.
   - **a** Bauxite
   - **b** Iron
   - **c** Lithium
   - **d** Sphalerite
   - **e** Gold
   - **f** Haematite
2. Describe the use of two minerals that are mined in Australia.
3. State what each of the following materials is used for, and explain why, based on its properties.
   - **a** Copper wiring
   - **b** Galvanised roof panels (e.g. Colorbond®)
   - **c** Soft-drink can
   - **d** Lithium-ion battery
4. Discuss the finite nature of resources extracted in Australia, with reference to environmental impact.

Planning investigations

see page 405

Read the aim, materials and method of Investigation 3.3 on page 500.

1. **a** Identify items in the materials list that are potentially hazardous.
   b Describe ways to minimise the risk.
2. **a** Identify the:
   - **i** independent variable (what you are changing).
   - **ii** dependent variable (what you are measuring).
   - **iii** controlled variable(s) (what stays the same).

   b Propose ways to improve the controlled variables that would improve this investigation.
3. Propose two alternative aims for this investigation (one for Part A and one for Part B) that would align with the content in this section.
4. Discuss the reliability, validity and ethicality of this investigation. Propose ways to improve any of these.
5. Propose two more types of data you could collect in this investigation that would improve the reliability of the results. Give reasons to support your response.

In context

Select two materials mined and/or produced in Australia.

a For each material, investigate the extraction process, local use, exports, environmental impacts and profits.

b Write a persuasive argument for which material is 'better' for mining in Australia.

Success criteria

- I can give three examples of finite minerals and/or resources mined in Australia.
- I can describe how the resources mined in Australia are used.

3.4 ▸ The impacts of extracting resources

Learning intention

At the end of this lesson, I will be able to recognise the environmental impacts of extracting and using Australian resources.

Key terms

biodiversity: the variety of organisms in an ecosystem

habitat: the place where an animal or plant naturally lives

Content group: Resources

Figure 3.13: The mining industry creates tens of thousands of jobs, from chemical engineers to architects, civil workers and drone pilots.

Figure 3.14: Scientists analyse waste water to consider the best approach for land rehabilitation.

Using and obtaining resources can damage the natural environment. It can be hard to balance the need for a resource with conserving the environment. It is important to understand how the resource will benefit society and how obtaining, using and disposing of it can damage the environment. We also consider how any damage can be minimised or reversed, and how these factors are perceived by different groups in the community.

How will we benefit from this resource?

Resources can provide us with food, shelter and other materials that improve our lives. We need to consider the benefits of using a resource and other ways that it can help society. For example, mining makes a significant contribution to Australia's economy, providing many people with jobs.

Does obtaining or using this resource damage the environment?

Obtaining or using a resource may change, pollute or destroy native **habitats** or reduce the **biodiversity** of an area. Burning fossil fuels releases carbon dioxide into the atmosphere at levels well above what would occur naturally. Carbon dioxide traps heat in the atmosphere that would normally escape into space. This has caused average global temperatures to rise and is contributing to climate change. If we are to limit the amount of carbon dioxide being emitted, we need to use alternatives to fossil fuels to produce energy.

Can we reduce the environmental impact?

Sometimes we need to make an environmental 'trade-off' if we cannot do without a resource. We must accept some environmental damage in return for obtaining or using the resource. In some cases, technologies and strategies can be used to lessen the impact on the environment. Mine owners are required to rehabilitate the land so that native plants and animals will return, but it will never be exactly how it was before the mine started.

Figure 3.15: The Super Pit is the biggest open-pit gold mine in Australia. Extracting this important resource impacts the environment.

Making choices involves consideration of conflicting interests

Before a resource is extracted and used, evidence and opinions are gathered. There are always people with different opinions, and this can make the final decision difficult to make. Coal is a resource that is frequently debated in Australia. Different groups will be affected in different ways, depending on the choices that are made (Table 3.2).

Table 3.2: Different points of view about mining and using coal

Group	Point of view
Mining companies	Want to extract as much coal as possible, to maximise profit, while balancing impact on the environment
Energy companies	Want to purchase coal cheaply to maximise profit and supply cheap electricity, while minimising greenhouse gas emissions
Coal industry workers	Want the industry to continue to provide them with work
Environmentally conscious people	Want the mining and burning of coal to stop so that carbon dioxide emissions are greatly reduced, and want access to cheap energy
Renewable energy companies	Want governments to support renewable energy technologies so that renewable energy becomes cheaper than fossil fuels
People living near mines and power plants	Are not happy with the damage to the local environment and are concerned that pollution is harming their health
Scientists	Have undertaken many studies providing evidence that burning fossil fuels such as coal is causing climate change

Learning Ladder

Materials

1. Identify three resources obtained from Earth, and describe a use for each one.
2. Classify the resources listed in Question 1 as 'necessary for life' or a 'luxury in life'. Provide reasons, making reference to their uses.
3. Explain how obtaining and using a resource can be useful in society.
4. Discuss how the natural environment can be affected by obtaining or using resources.
5. **a** Identify the gas that is released into the atmosphere when a fossil fuel is burned.
   b Evaluate the relationship between the impact of this gas on the environment and the need to extract and manufacture a range of materials that sustain human lifestyles.

Communicating

see page 429

Consider the information in Table 3.2.

1. Propose an appropriate way to communicate the information to your local council.
2. Describe how you might use digital technologies to communicate the information to an online audience.
3. Construct a presentation to communicate the information in a webinar.
4. Prepare presentation notes or cue cards to use alongside the presentation you constructed in Question 3.
5. Collect second-hand evidence to support the information and add it to your presentation.

In context

Stopping coal mining in Australia would significantly reduce the country's income but would stop the considerable environmental damage caused by the mining and use of coal. Does the benefit of conserving the environment outweigh the cost to the economy? Document your findings in a scientific report (see the Science how-to section on pages 434–36) and use evidence to support your response.

Success criteria

- I can state the impact on the environment and on the economy of obtaining and using resources.
- I can describe some different points of view on the use of non-renewable resources in Australia.

3·5 ▸ Chemical bonding

Learning intention

At the end of this lesson, I will be able to describe chemical bonding.

Key terms

atom: the smallest particle of a chemical element; made up of electrons, protons and neutrons

atomic number (*Z*): the number of protons in an atom

chemical bond: an electrostatic force that connects atoms to one another

compound: a pure substance made up of two or more types of atoms bonded in fixed ratios

electron shell: the area around the nucleus where a specific number of electrons orbit at a specific energy level

electrostatic force: a force of attraction between positive and negative particles

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

Content group: Bonding

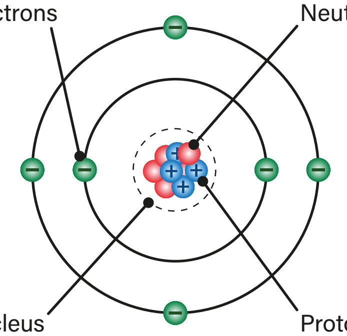


Figure 3.16: Atoms contain protons and neutrons in the nucleus and negatively charged electrons orbiting the nucleus.

Earth's resources are made up of chemical elements that come together in various ways. The atoms of these elements join through chemical bonds to make a substance or material. Within atoms, subatomic particles called electrons are responsible for enabling chemical bonding to take place.

Atoms form chemical bonds to become stable

There are 118 known chemical **elements**. Each element is made up of one type of **atom** and is defined by how many protons are in the atom's nucleus – the **atomic number (*Z*)**. On their own, atoms are usually unstable. To achieve stability, they must obtain a suitable arrangement of electrons in the **electron shells** that surround the nucleus. They do this by losing, gaining or sharing electrons, which leads to oppositely charged particles becoming attracted to each other. This **electrostatic force** connects atoms to one another in a **chemical bond**, resulting in a stable substance.

Pure substances can be elements or compounds

Elements are pure substances that are made up of the same type of atoms. For example, the non-metal nitrogen contains only nitrogen atoms, each with 7 protons (+) and 7 electrons (–). All the known elements are listed in the periodic table of elements (Figure 3.17). Examples of elemental substances are copper metal (Cu), oxygen gas (O_2) and diamond, or pure carbon (C).

A **compound** is a chemical substance made up of atoms of two or more elements held together in fixed ratios by chemical bonds. Some examples of compounds are water (H_2O), carbon dioxide (CO_2), glucose ($C_6H_{12}O_6$) and table salt (NaCl).

Compounds and elements both rely on chemical bonds to hold their atoms together so that materials exist as we know them.

There are three types of chemical bonds

The type of chemical bond that will form between atoms depends on the types of elements (metal or non-metal, Figure 3.17). In general, there are three main types of bonding. The types of elements usually involved in each are as follows:

- **metallic bonding:** metals bonded to other metals
- **ionic bonding:** metals bonded to non-metals
- **covalent bonding:** non-metals bonded to non-metals.

Noble gases, in group 18 of the periodic table, are highly unlikely to form chemical bonds because their atoms already have a stable arrangement of electrons. The electron configuration around the nucleus of an atom is explored in Section 3.6.

Figure 3.18: Ionic bonds hold metal and non-metal atoms together in salt (NaCl).

Figure 3.17: The elements of the periodic table can generally be categorised as either metals or non-metals.

Metals

Non-metals

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							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 Aluminum	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

The red zig-zag line approximately separates metals from non-metals.

Learning Ladder

Materials

1. Classify the following materials as elements or compounds.
   - **a** Water (H_2O)
   - **b** Copper wire (Cu)
   - **c** Table salt (NaCl)
   - **d** Diamond (C)
2. Describe the bonding in the materials in Question 1 as metallic, ionic or covalent. Give a reason.
3. Explain how each of the materials in Question 1 is commonly used in society. Predict which type of bonding is the strongest, and explain why.

Problem-solving

see page 425

Some elements have characteristics of both metals and non-metals, which can be problematic when elements are organised into the periodic table.

1. Propose how this has been considered in the periodic table, with reference to Figures 3.17 and 3.19 (pages 94–95).
2. In terms of types of bonding, explain a problem that could arise because there are many elements that are not easily classified as metals or non-metals.
3. Based on the metal–non-metal border in Figure 3.17, classify the bonding in the following materials as metal, ionic or covalent.
   - **a** Silicon (Si)
   - **b** Germanium oxide (GeO_2)
   - **c** Sodium chloride (NaCl)
   - **d** Antimony trichloride ($SbCl_3$)
   - **e** Pure copper (Cu)

In context

Select a metalloid (the green elements) from Figure 3.19 and use the internet to explore its properties and common uses. Discuss how its properties distinguish it from metals and non-metals and are linked to its uses.

Success criteria

- I can list the three main types of chemical bonding.
- I can use the periodic table to classify metallic, ionic and covalent materials.

Periodic table of elements

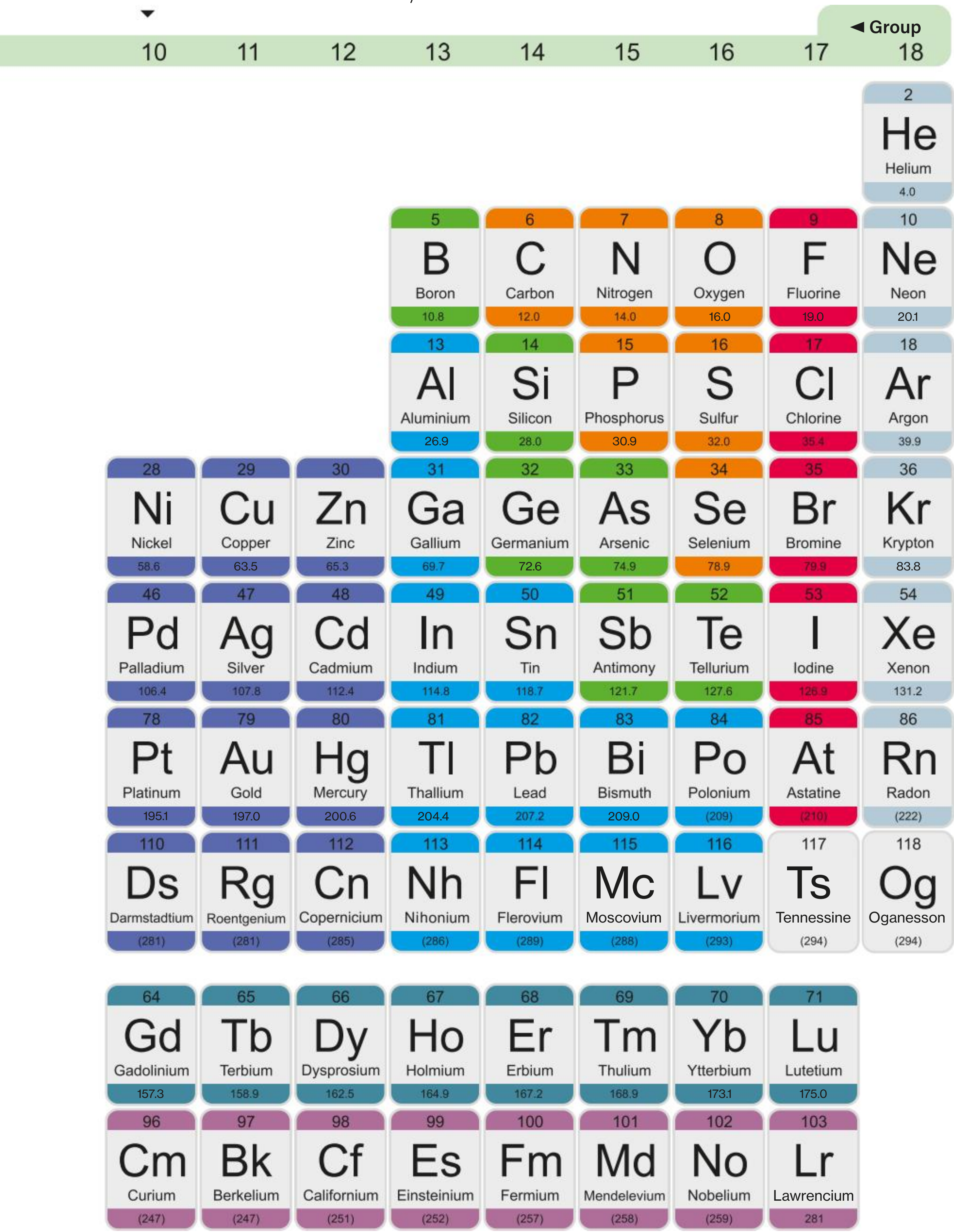
1	Atomic number
H	Chemical symbol
Hydrogen	Element name
1.0	Atomic mass

- Halogen
- Non-metal
- Alkali metal
- Alkaline earth metal
- Actinoid
- Transition metal
- Other metal
- Metalloid
- Lanthanoid
- Noble gas

Period	1	2	3	4	5	6	7	8	9
1	1 H Hydrogen 1.0								
2	3 Li Lithium 6.9	4 Be Beryllium 9.0							
3	11 Na Sodium 22.9	12 Mg Magnesium 24.3							
4	19 K Potassium 39.1	20 Ca Calcium 40.0	21 Sc Scandium 44.9	22 Ti Titanium 47.8	23 V Vanadium 50.9	24 Cr Chromium 52.0	25 Mn Manganese 54.9	26 Fe Iron 55.8	27 Co Cobalt 58.9
5	37 Rb Rubidium 85.4	38 Sr Strontium 87.6	39 Y Yttrium 88.9	40 Zr Zirconium 91.2	41 Nb Niobium 92.9	42 Mo Molybdenum 95.9	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9
6	55 Cs Caesium 132.9	56 Ba Barium 137.3	57–71 Lanthanoids	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.9	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2
7	87 Fr Francium (223)	88 Ra Radium (226)	89–103 Actinoids	104 Rf Rutherfordium (267)	105 Db Dubnium (268)	106 Sg Seaborgium (269)	107 Bh Bohrium (270)	108 Hs Hassium (269)	109 Mt Meitnerium (278)

Lanthanoids	57 La Lanthanum 138.9	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.4	63 Eu Europium 152.0
Actinoids	89 Ac Actinium (227)	90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)

Figure 3.19: The periodic table shows all the known elements and their chemical symbols.



3·6 ▸ Electron configuration

Learning intention

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

- describe the structure of atoms in terms of electron shells and energy levels
- use valency to describe the number of electrons an atom needs to gain, lose or share in order to achieve a stable electron configuration.

Key terms

Bohr diagram: a diagram showing the electron configuration of an atom

electron configuration: the organisation of electrons into shells around the nucleus of atoms

noble gas configuration: the valence electron configuration that occurs through chemical bonding

octet rule: the tendency of atoms to achieve eight electrons in their valence (outer) shell to be stable

valence electrons: electrons that occupy the outermost shell of an atom

valence shell: the outermost shell of an atom

Content group: Bonding

To understand why and how chemical bonding occurs, you must understand how electrons are distributed throughout an atom. All atoms are made up of protons, neutrons and electrons.

Electrons exist in energy levels

Recall that protons and neutrons make up the nucleus of an atom, while electrons orbit around the nucleus. The more energy the electrons have, the further they orbit from the nucleus. The orbits are called **electron shells**.

The number of shells an atom has depends on how many electrons it has. As atomic number (Z) increases, the number of electrons also increases. The period on the periodic table that an element is in corresponds to the number of shells an atom of the element has. For example, sodium is in period 3 of the periodic table, so a sodium atom has three electron shells, or energy levels. The maximum number of electrons in any shell is $2n^2$, where n is the shell number (see Table 3.3). The electron configuration is shown in a **Bohr diagram** (Figure 3.20).

Figure 3.20: A Bohr diagram can be used to show the electron configuration of an atom.

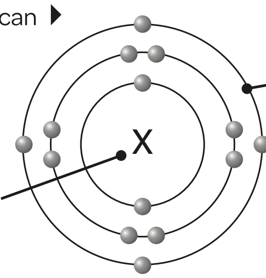


Table 3.3: The maximum number of electrons by shell number

Shell number (n)	Maximum number of electrons ($2n^2$)
1	2
2	8
3	18
4	32

Bohr diagrams show electron configurations

The rules for drawing Bohr diagrams are as follows:

- The electrons fill the lowest energy shells first (i.e. those closest to the nucleus).
- The outer shell (the **valence shell**) can have only eight electrons. For the first 20 elements, the electron shells follow a 2, 8, 8, 2 pattern (**electron configuration**). That is, we move to the third shell once the second shell has eight electrons. Elements larger than calcium do not follow this rule.

Lithium has three electrons. The first shell can only hold two, so the third electron will be in the second shell. This configuration is written as 2, 1.

Potassium has 19 electrons. The first shell has two, and the second and third shells can hold eight. We put one electron in the fourth shell. This gives potassium a configuration of 2, 8, 8, 1.

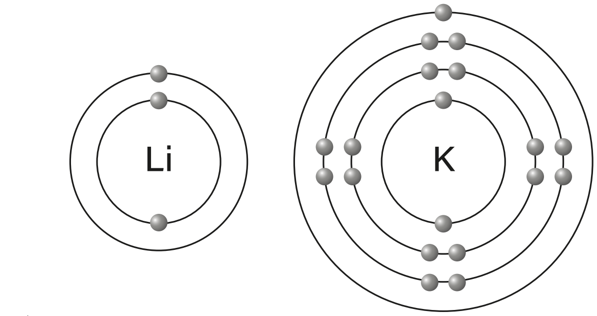


Figure 3.21: These Bohr diagrams represent the electron configurations of lithium and potassium.

Chemical bonding achieves a stable electron configuration

Apart from helium, which has two electrons, noble gases have eight electrons in their valence (outer) shell. We refer to this as 'full', even though from the third shell onwards there is room for more than eight electrons. Having a 'full' outer shell makes them very stable, which is why they tend not to form chemical bonds with other atoms.

All atoms are most stable when they have a full valence shell; therefore, chemical bonding occurs so that atoms can achieve **noble gas configuration** – a full outer shell. This is sometimes called the **octet rule**. Exceptions to this rule include atoms with fewer than five electrons. They can be satisfied with just one shell, which can hold only two electrons. In this case, the atom is stable with just two electrons on the outer shell (e.g. helium).

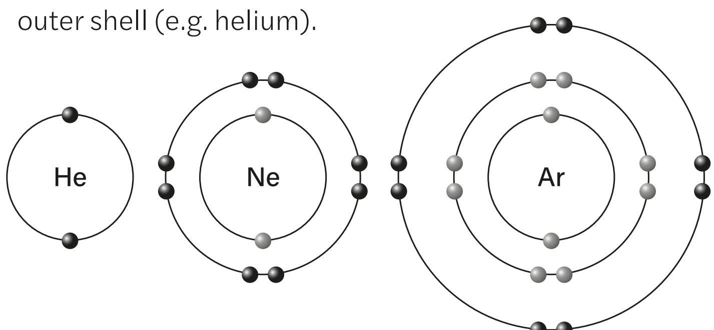


Figure 3.22: Electron configurations of the first three noble gases, showing 'full' and stable valence shells.

How an atom achieves a stable octet depends on its number of **valence electrons**. Atoms with one–three valence electrons tend to lose electrons, atoms with four electrons tend to share them, and atoms with five–seven electrons gain or share them.

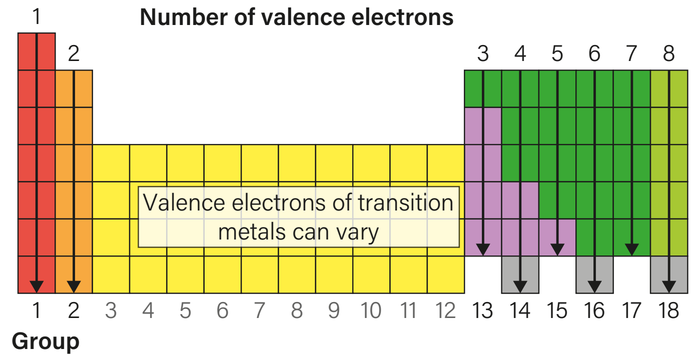


Figure 3.23: The periodic table can be used to determine how many valence electrons the atoms of main group elements have. As transition metal valencies can vary, they are sometimes represented using roman numerals when the compound is written in words.

Learning Ladder

Materials

1. Use the periodic table to determine whether the following elements are likely to lose, gain or share electrons to achieve noble gas configuration.
   a Calcium **b** Carbon **c** Chlorine
   d Aluminium **e** Nitrogen
2. State why noble gases are unlikely to form chemical bonds with other atoms.
3. Propose why noble gases are often used to prevent metals reacting with oxygen during welding.

Problem-solving

see page 425

1. Describe how you could help a friend understand sulfur's electron configuration, 2, 8, 6.
2. Explain how you would determine whether an atom will gain, lose or share electrons to become stable.
3. Determine the maximum number of electrons that can fit on the fifth and sixth electron shells.
4. Assess the structure of the periodic table. Consider electron configuration, valence electrons and types of bonding in your discussion.

In context

Construct a model (digital or physical) of a calcium atom that you could use to teach someone about electron shells.

Success criteria

- I can determine the electron configuration of any of the first 20 elements.
- I can explain noble gas configuration and how it relates to chemical bonding.

3·7 ► Ionic bonding

Learning intention

At the end of this lesson, I will be able to describe how ionic bonds are formed.

Key terms

anion: a negatively charged ion

cation: a positively charged ion

chemical formula: chemical symbols showing the ratio of elements to one another in a compound

ion: an atom with unequal numbers of protons and electrons; an atom with a positive or negative charge

ionic bond: an electrostatic force between a cation and an anion

lattice: a three-dimensional repeating structure or pattern

valency: the attracting power of an atom; ion charge

Content group: Bonding

Ionic bonding involves the transfer of electrons between atoms and is one of the main ways in which atoms come together to form new substances. The process produces oppositely charged ions, which are attracted to each other and form strong ionic bonds. Models can help to visualise the process of how ions are formed and how they come together in different ratios to form a variety of ionic compounds, each with a unique chemical formula.

Atoms lose or gain electrons to form ions

Atoms have the same number of protons (+) and electrons (−), so they have no overall charge; they are neutral. To achieve stability, atoms might lose or gain electrons to become **ions**. When this occurs, the number of protons and electrons is no longer equal, resulting in an overall charge. When atoms lose electrons, they form positively charged ions called **cations**. When they gain electrons, they form negatively charged ions called **anions** (Figure 3.24).

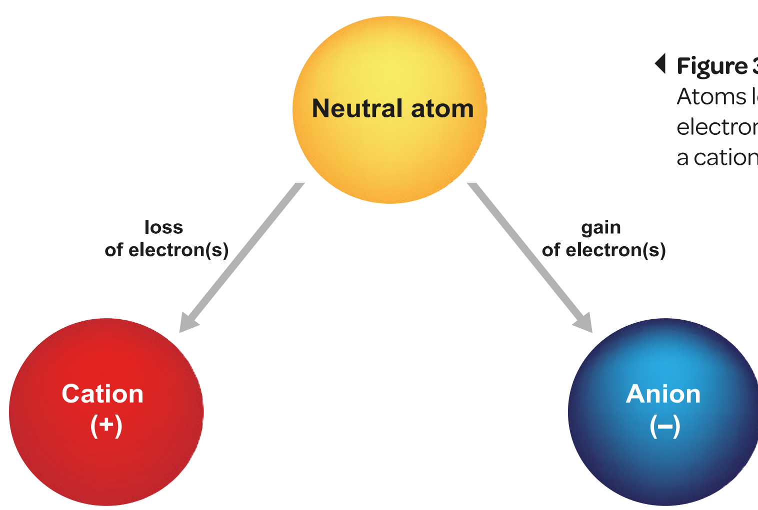


Figure 3.24: Atoms lose or gain electrons to become a cation or an anion.

Ions are shown by writing a plus (+) or minus (−) sign in superscript on the right side of the elemental symbol, such as Na^+ and Cl^-. Some atoms gain or lose more than one electron. This is shown by writing a number in front of the + or −, such as $Mg^{2+}$and O^{2-}. The charge of an ion is also called the **valency**, or the attracting power of an atom, which indicates the number of electrons an atom needs to gain or lose in order to achieve a stable noble gas configuration (Figure 3.25).

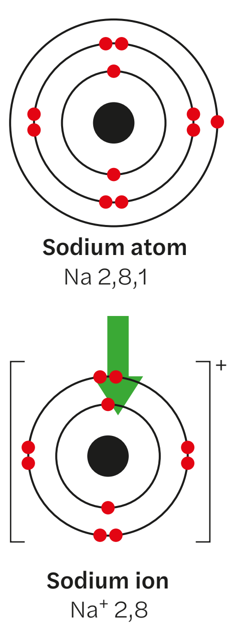
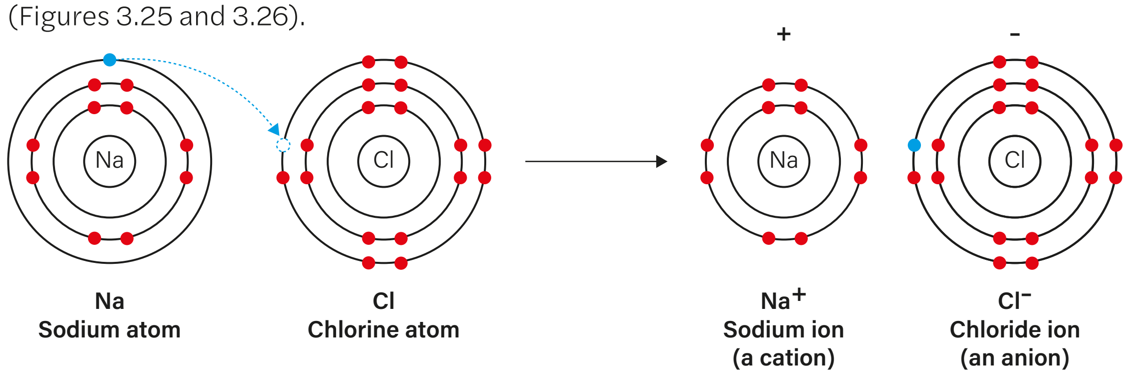


Figure 3.25: The sodium atom loses one electron to achieve a stable noble gas configuration and form a sodium ion (cation).

Ionic bonding can be modelled using diagrams

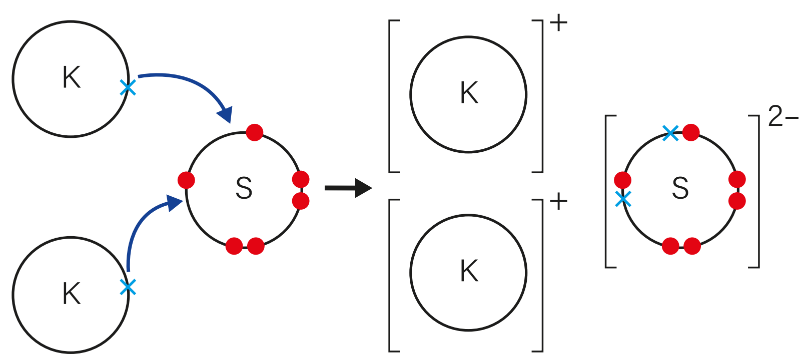
The electrostatic force between cations and anions is an **ionic bond**. The process of ionic bonding can be shown using diagrams that represent the formation of ions and the transfer of electrons between atoms (Figures 3.25 and 3.26).

Figure 3.26: This diagram is used to show a sodium atom losing an electron which is gained by a chlorine atom, resulting in each having a noble gas configuration. They become oppositely charged ions, which forms an attraction called an ionic bond.



Since only valence electrons are involved in bonding, only these electrons are essential in diagrams. Inner-shell electrons can be excluded. Simplifying diagrams in this way is especially helpful when displaying ionic bonding between larger atoms such as potassium ($Z = 19$) and sulfur ($Z = 16$), as represented in Figure 3.27.

Figure 3.27: Sometimes only valence electrons are used in diagrams, since they are responsible for bonding.



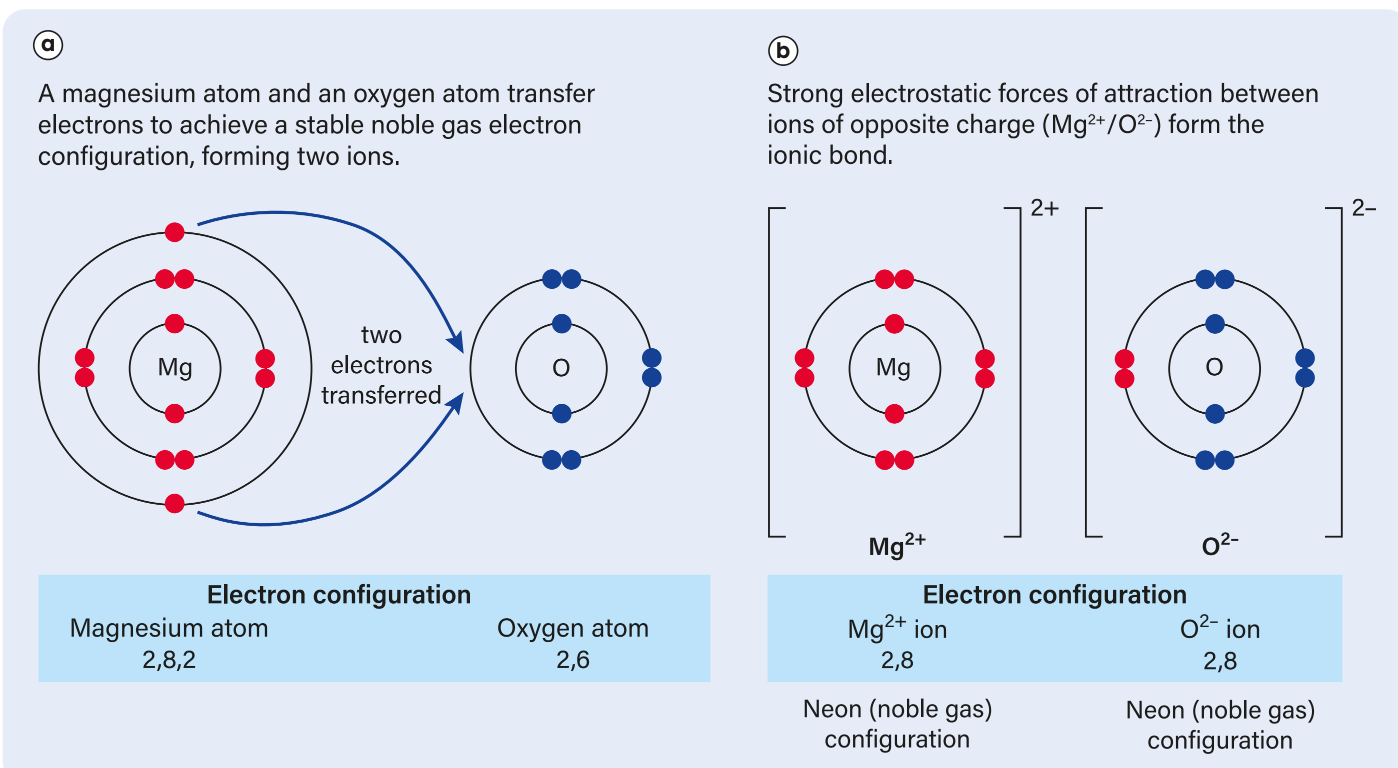


Figure 3.28: The ionic bonding of magnesium oxide

Ionic compounds form a 3D lattice

When cations and anions bond, they form an ionic compound, usually made up of a metal and a non-metal. The ions connect in a repeating pattern, alternating cations and anions, to form a three-dimensional ionic **lattice**. The ionic bonds in an ionic compound are very strong because of the multidirectional electrostatic attraction between the positive and negative ions.

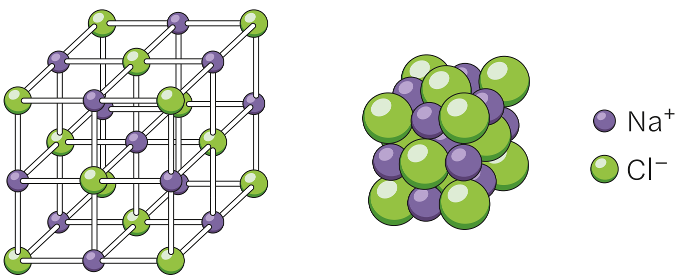


Figure 3.29: Cations and anions bond together to form a three-dimensional lattice.

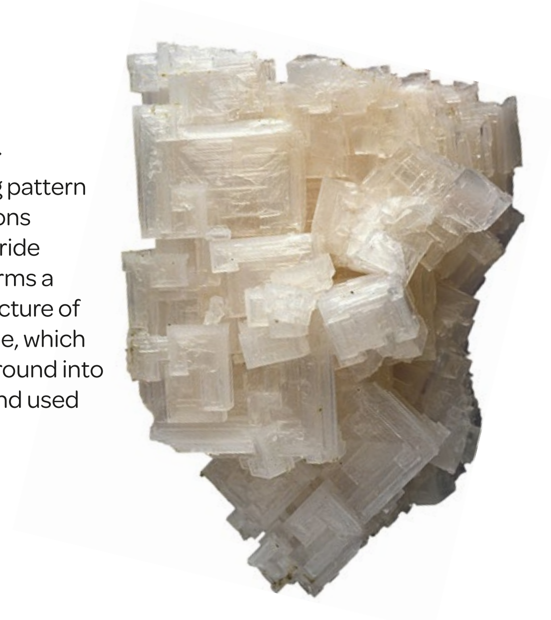


Figure 3.30: The alternating pattern of sodium cations (Na+) and chloride anions (Cl–) forms a crystalline structure of sodium chloride, which is commonly ground into fine granules and used as table salt.

Chemical formulas are used to represent compounds

A **chemical formula** is a shorthand way of writing the name of an element or a compound. It tells you the type and ratio of atoms in a compound. Symbols represent the elements present, and the subscript number indicates the ion ratio, or proportion of atoms in the repeating pattern. You can then use these formulas to write chemical equations that model reactions.

When cations and anions come together, their ion charges cancel out to form a neutral compound overall. For example, when Na^+ and Cl^- combine in a 1:1 ratio, they form a neutral material with no overall charge. This is why the chemical formula for sodium chloride (NaCl) excludes charges and subscripts.

This also explains why not all ionic compounds combine in a 1:1 ratio like sodium chloride. It depends on the valency charge of the ions involved.

Notice, in Figure 3.27, that two potassium ions are required but only one sulfur ion. This shows the ratio in which they come together to form a neutral compound. Therefore, the chemical formula for potassium sulfide is K_2S, because two potassium ions are required for every one sulfur ion – a 2:1 ratio.

Diagrams can be used to model bonding and to work out the ratio of atoms when determining the chemical formula. However, this can be time consuming. To quickly determine the chemical formula for an ionic compound, you can use the swap-and-drop method (Table 3.4).

Tips for writing ionic chemical formulas:

- Do not include ion charges in the final chemical formula.
- There is no charge on the subscript because it is quantifying the ionic ratio.
- The swap-and-drop method is simply a tool or trick used to determine chemical formulas.

Table 3.4: The swap-and-drop method for determining the chemical formula of an ionic compound

Step	Example: Lead(IV) oxide	Barium chloride	Chromium(III) oxide
1 Write the ion symbols with the positive ion on the left and the negative ion on the right	Pb^{4+} O^{2-}	Ba^{2+} Cl^{1-}	Cr^{3+} O^{2-}
2 Swap the superscript charge numbers to become the subscript values for the other ion.	Pb^{4+} O^{2-} ↓ Pb_2O_4	Ba^{2+} Cl^{1-} ↓ $BaCl_2$	Cr^{3+} O^{2-} ↓ Cr_2O_3
3 Simplify, using the lowest common factor.	PbO_2	$BaCl_2$	Cr_2O_3

Figure 3.31: Salt accumulates on the mountain slopes of Peru, where it is mined using traditional terraced methods.

Learning Ladder

Materials

1. Identify the two types of atoms required to form an ionic bond.
2. Describe the properties of each of the atoms you identified in Question 1 that allow them to form an ionic bond.
3. **a** Explain how iron can form two different compounds with chlorine.
   b Describe how these compounds might be different from each other.

Communicating

see page 429

1. Propose the advantages of using chemical formulas instead of chemical names.
2. Describe why it might be more appropriate to use digital technologies to represent a three-dimensional ionic lattice.
3. Construct diagrams to show the electron transfer that forms these compounds.
   a KBr
   b PbO_2
   c Li_3N
   d Al_2S_3

In context

Investigate where calcium hydroxide, calcium carbonate and monosodium glutamate are found in your home. Identify their common names and formulas, and describe their purposes.

Success criteria

- I can use models to represent the formation of ions and ionic bonds.
- I can construct chemical formulas for some common ionic compounds.

3·8 ▸ Metallic bonding

Learning intention

At the end of this lesson, I will be able to describe the metallic bonding model.

Key terms

alloy: a metallic substance made of a metallic element and at least one other element, usually a metal

delocalised electrons: electrons that are free to move about the substance

metallic bond: a bond in which free electrons move around metal ions

Investigation 3.8

Properties of pure versus alloy metals, page 502

Content group: Bonding

Figure 3.32: Silver and gold are examples of pure metals that are often used for jewellery.

Figure 3.33: Brass is a mixture of copper and zinc, popular for its lustre and bright gold appearance.

We encounter metallic substances all the time, from the jewellery we wear to the instruments we play. Sometimes these metals contain just one type of element, such as copper. But metals can also be made up of more than one type of metal; for example, brass is a mixture of copper and zinc. In either case, **metallic bonds** enable the formation of metallic substances. The metallic bonding model is used to illustrate how metallic bonds are formed and to explain the properties of metals.

Metal cations are bound together by free electrons

In metallic bonding, metal atoms lose their valence electrons to become stable, rather than gaining or sharing electrons. The lost electrons form a 'sea' of **delocalised electrons** (–) around the metallic cations (+) in fixed rows. This forms a three-dimensional metallic lattice of closely packed particles, held in place by the electrostatic attraction between positive cations and negative electrons.

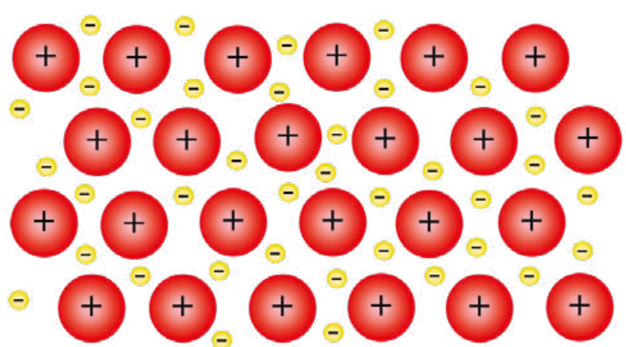
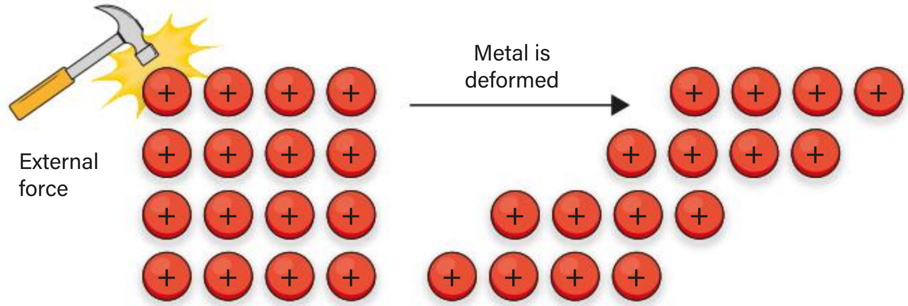
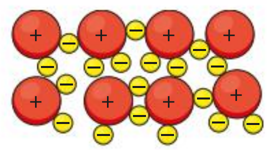
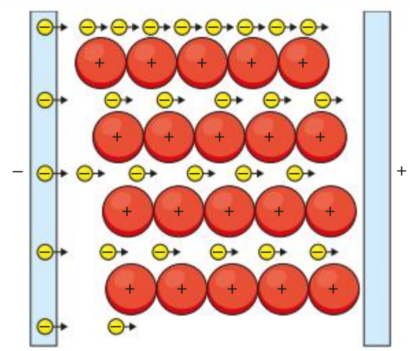
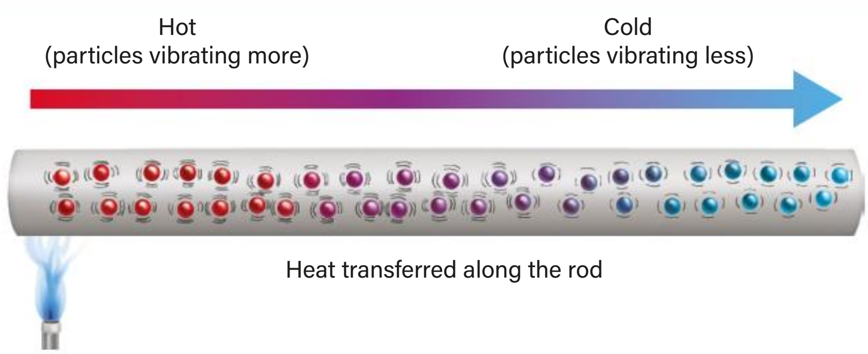
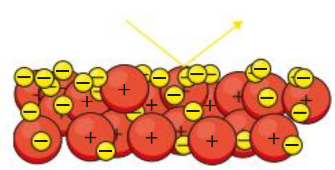


Figure 3.34: The metallic bonding model is illustrated by rows of cations in fixed positions held together by a 'sea' of delocalised electrons.

The metallic bonding model explains properties of metals

The properties of metals can be explained by the metallic bonding model, as shown in Table 3.5.

Table 3.5: Using the metallic bonding model to explain the properties of metals

Property	Aspect of metallic bonding model
Malleable	The delocalised electrons can move freely among the metal cations, which allows layers of cations to slide past each other, rather than break, when a force is applied 
Typically have a high melting or boiling temperature	Strong electrostatic forces between cations and delocalised electrons hold them together and require a lot of energy to break. 
Good electrical conductivity	Delocalised electrons transfer voltage (electricity) through the material. 
Good thermal conductivity	Delocalised electrons transfer kinetic vibrations through the material. 
Lustrous (shiny)	Delocalised electrons reflect light as they move along the surface of the metal, creating a shiny reflection. 

Alloys have different properties from pure metals

Metallic substances made of more than one type of metal are called **alloys**. In an alloy lattice, the rows of cations cannot easily slide past each other. This is because atoms of different metals are different sizes, which disrupts the regular, repeating lattice of a pure metal.

Alloys have different properties from pure metals. They are stronger and more rigid, and so are less malleable. Pure metals are used where malleability is important, such as in wiring. Alloys are often used in construction because of their strength and resistance to weathering.

There are two types of alloys: substitutional and interstitial. In substitutional alloys, the metallic atoms being mixed are similar in size, but just different enough to prevent the rows from sliding past each other easily. Interstitial alloys contain metals that are very different in size, so that the smaller atoms fill the gaps between the rows of larger metallic cations. Although the rows of cations are still aligned, they are unable to slide past each other due to the smaller atoms acting as a wedge, in the same way that wheel chocks are used to stop vehicles from rolling away. This is described visually in Table 3.6.

Bronze, made of copper and tin, is a type of alloy you are probably already familiar with. Bronze is known for its hardness and resistance to corrosion, which makes it ideal for items that need to withstand wear and tear, such as coins, medals and statues (because it holds up well outdoors without rusting). Bronze is also used in bearings, boat propellers and electrical connectors, since it does not easily spark or corrode. Its unique properties make bronze an excellent choice for many practical and decorative items we encounter regularly.

Table 3.6: Types of metals and alloys

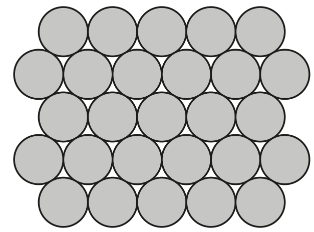
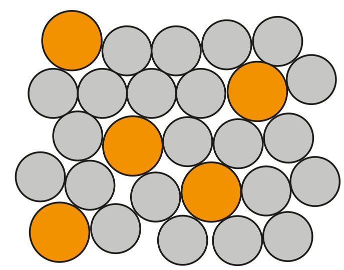
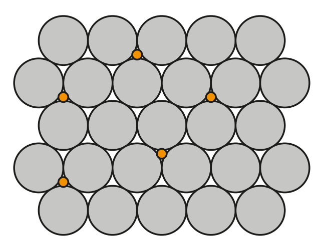
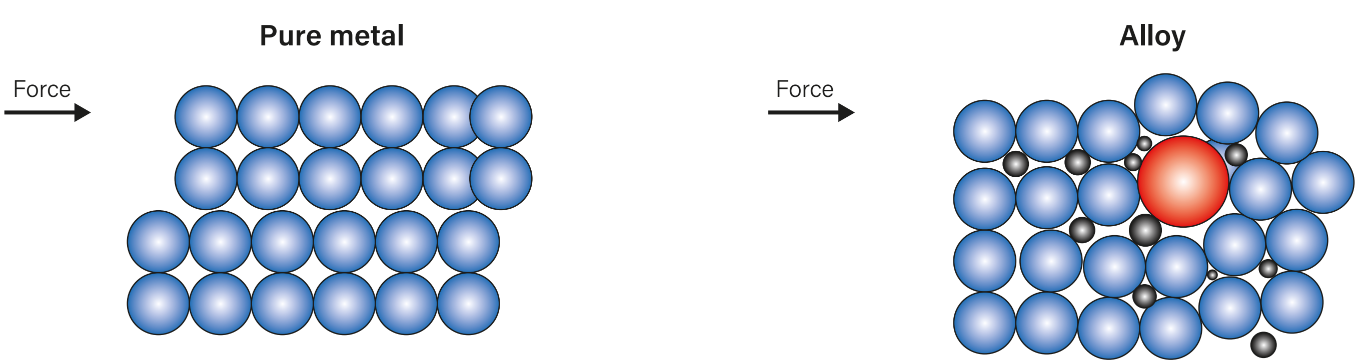
Type	Description
Pure metal	The rows of cations are made up of only one type of atom, so the rows are aligned and able to slide easily when a force is applied. 
Substitutional alloy	The atoms of the different metals are similar sizes. This disrupts the regular, repeating rows of the metallic lattice. 
Interstitial alloy	The atoms of the different metals are very different sizes. Much smaller atoms fit into the gaps in the cation rows, preventing them from sliding easily. Carbon is often used to make this type of alloy, even though it is not a metal. 

Figure 3.35: Atoms in pure metals and alloys



In a pure metal, the atoms are the same size and can slip past each other.

In an alloy, the atoms are different sizes, which prevents them slipping past each other.

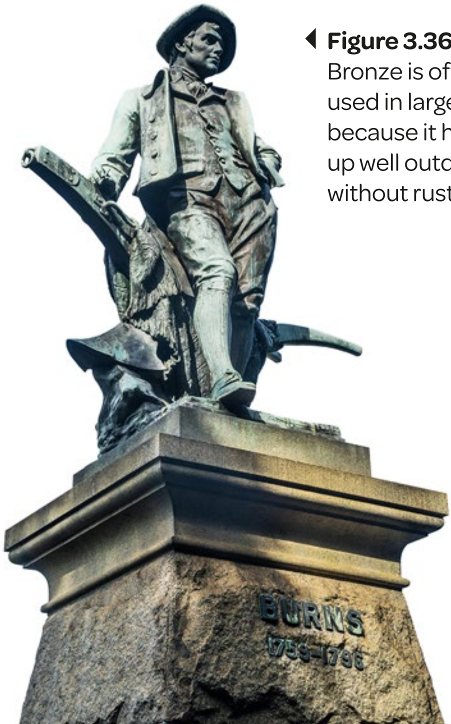


Figure 3.36: Bronze is often used in large statues because it holds up well outdoors without rusting.

Figure 3.37: Wheel chocks for this truck prevent it from rolling away, much like small atoms prevent rows of larger cations sliding past each other by filling the gaps in a metallic lattice to make an interstitial alloy.

Learning Ladder

Materials

1. Classify the following combinations of elements as either substitutional or interstitial. Refer back to the periodic table on pages 94–95 to get an idea of their relative size.
   a Copper and zinc
   b Iron and carbon
   c Tin and lead
   d Titanium and copper
   e Silver and aluminium
2. Identify three common items that are made of pure metal, and describe their properties.
3. Bronze is an alloy of copper and is much stronger than the pure metal. With reference to the metallic bonding model, explain why bronze is not used in place of copper for electrical wiring.
4. Conduct an online search to determine why lead (Pb) is toxic to the environment.
5. Discuss how each of the following substances is used in relation to its properties and the metallic bonding model.
   a Gold
   b Titanium alloy
   c Solder (tin–lead alloy)

Planning investigations

see page 405

Read the aim, materials and method of Investigation 3.8 on page 502.

1. **a** Identify items in the materials list that are potentially hazardous.
   b Describe ways to minimise the risk.
2. **a** Identify the:
   i independent variable (what you are changing)
   ii dependent variable (what you are measuring)
   iii controlled variable(s) (what stays the same).
   b Propose ways to improve the controlled variables that would improve this investigation.
3. Propose two alternative aims for this investigation (one for Part A and one for Part B) that would align with the content in this section.
4. Discuss the reliability, validity and ethicality of this investigation. Propose ways to improve any of these areas.

In context

For a substance to conduct electricity, it must have free-moving charged particles. Both metallic and ionic lattices are made up of positive and negative particles. Explain why metals can conduct electricity, but solid ionic substances cannot.

Success criteria

- I can distinguish between pure metals and metallic alloys.
- I can use the metallic bonding model to explain the properties of metals.

3·9 ▸ Covalent bonding

Learning intention

At the end of this lesson, I will be able to describe covalent bonding.

Key terms

covalent bond: a bond in which two atoms share one or more pairs of electrons

covalent network solid: a continuous network of atoms that are joined together through covalent bonds (not discrete); also called 'giant covalent solid'

diatomic molecules: molecules made up of two atoms

double covalent bond: two pairs of electrons shared between two atoms

molecular formula: a chemical formula for molecules showing the type and exact number of atoms in the substance

molecule: two or more atoms covalently bonded to form a discrete or separate unit of atoms

single covalent bond: one pair of electrons shared between two atoms

triple covalent bond: three pairs of electrons shared between two atoms

Content group: Bonding

Non-metallic atoms can form new substances by sharing electrons with other atoms, rather than by losing or gaining electrons. Substances formed in this way are called covalent materials.

Covalent substances are bound together by shared electrons

Atoms typically want four pairs of electrons on their outer shell for a total of eight electrons – a stable configuration. When two or more non-metallic atoms bond, they share electrons in their valence shells to achieve a stable configuration. The substance formed is called a **covalent compound**. For example, hydrogen and chlorine each need one more electron to achieve a stable noble gas configuration. Sharing their unpaired valence electrons with each other completes the pair, resulting in a stable configuration and the compound HCl. The shared electrons belong to both hydrogen and chlorine at the same time (Figure 3.38).

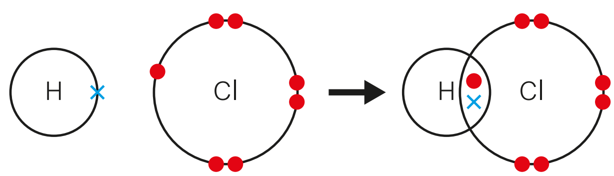


Figure 3.38: The unpaired electrons of hydrogen and chlorine can be shared by the two atoms, achieving a stable configuration for each atom.

The negatively shared electrons orbit the positive nuclei of the bonded atoms, producing a strong electrostatic force that holds them together. This is a **covalent bond** (Figure 3.39).

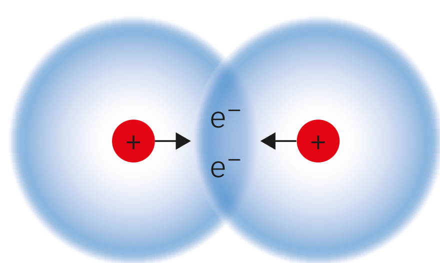
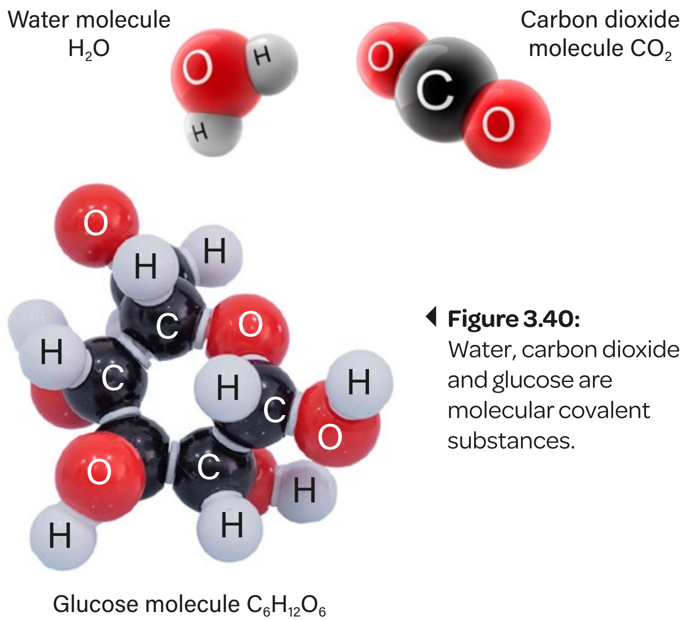


Figure 3.39: A covalent bond is the electrostatic force between the positive nuclei of atoms and the negatively charged shared pair of electrons.

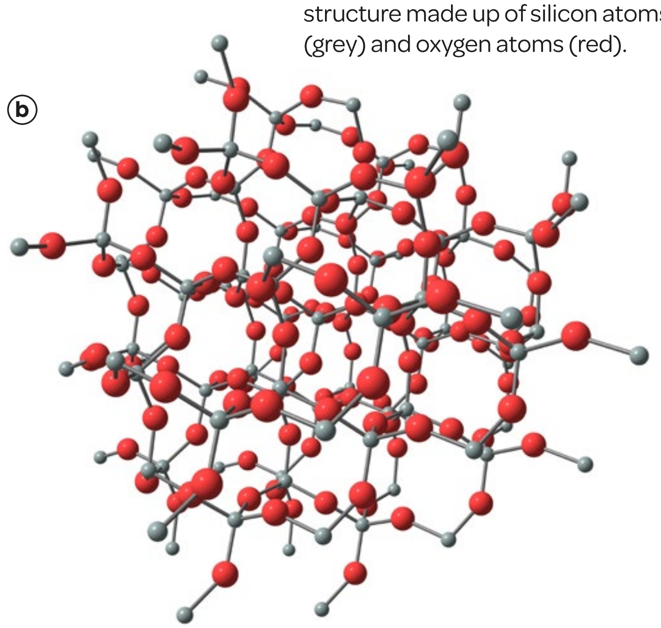
A **molecule** is the smallest unit of a covalent substance that is a discrete unit of atoms. Water (H_2O), carbon dioxide (CO_2) and glucose ($C_6H_{12}O_6$) are examples of molecular covalent substances (Figure 3.40).



◀ **Figure 3.40:** Water, carbon dioxide and glucose are molecular covalent substances.

Covalent substances can also form giant **covalent network solids** – continuous arrangements of atoms joined through covalent bonds throughout the material. Diamond (C) and silica (SiO_2) are examples of covalent network solids. They are not discrete molecules, because they have continuous chemical bonding throughout the entire structure (Figure 3.41).

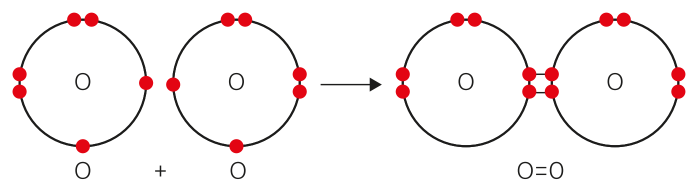
◀ **Figure 3.41:** Covalent network solids. (a) Diamond is made of carbon atoms covalently bonded to each other in a regular, repeating and continuous pattern. (b) Silica has a giant covalent structure made up of silicon atoms (grey) and oxygen atoms (red).



Atoms can share more than one pair of electrons

When one pair of electrons is shared between two atoms, it is called a **single covalent bond**, usually represented by a line (H–Cl). If an atom needs more than one more electron to satisfy its octet, it can either form more single covalent bonds with other atoms or form multiple bonds with the one atom.

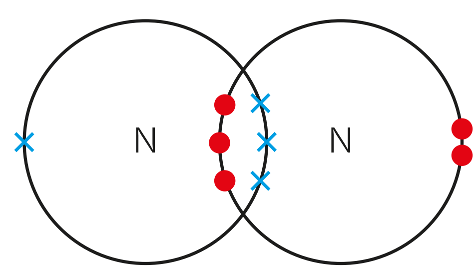
For example, oxygen has six electrons on its outer shell. Four are paired and two are unpaired. To become stable, an oxygen atom can share its unpaired electrons with another oxygen atom so that each achieves an octet of four pairs of electrons, two of which are shared, as shown in Figure 3.42.



▲ **Figure 3.42:** Two oxygen atoms share their unpaired electrons to form a double covalent bond.

When two pairs of electrons are shared between two atoms, it forms a **double covalent bond**. This can be represented by two lines (O=O). Each line represents two electrons.

Atoms that need three more electrons to be stable can form **triple covalent bonds**, sharing a total of six electrons (three pairs) between two atoms; for example, nitrogen gas (N_2) (Figure 3.43).



▲ **Figure 3.43:** In nitrogen gas (N_2), two nitrogen atoms share six electrons to form a triple covalent bond.

The tendency for non-metals to form single and multiple bonds with themselves is why many non-metallic gases exist as **diatomic molecules** – molecules that are made up of two atoms; for example, hydrogen (H_2), oxygen (O_2), nitrogen (N_2), fluorine (F_2), chlorine (Cl_2), bromine (Br_2) and iodine (I_2).

Dot formulas and chemical formulas are used to represent covalent substances

A chemical formula indicates the type and ratio of atoms in a substance. Chemical formulas for covalent molecules are called **molecular formulas** because they exist as a discrete unit with an exact number of atoms, rather than a repeating ratio.

In a chemical formula, the elements are represented by letters, and subscript numbers indicate how many of each atom are in the molecule (e.g. H_2O).

Dot formulas show the symbols and valence (outer shell) electrons of all bonding atoms, using dots and/or crosses to represent valence electrons. If you know the chemical formula, you can deduce the dot formula. Table 3.7 shows you how to determine the dot formula for water from its chemical formula, H_2O.

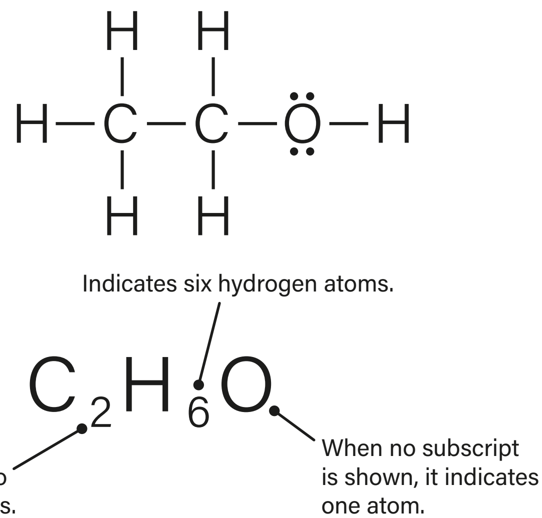
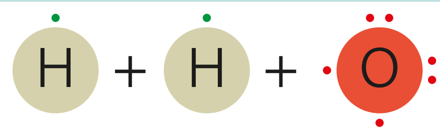
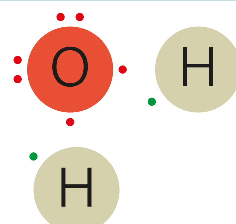
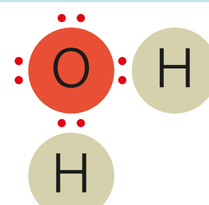
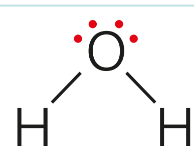


Figure 3.44: The dot formula for a molecule of ethanol shows all of the covalent bonds that hold the molecule together. The chemical formula includes subscript values to indicate how many of each atom make up the molecule, without having to see the whole structure.

Table 3.7: How to construct the dot formula for water (H_2O)

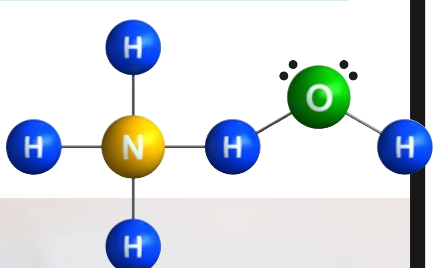
Step	Explanation	Constructing a dot formula
1 Write the symbol for each atom in the molecule and draw dots to represent valence electrons.	H_2O tells us there are two hydrogen atoms and one oxygen atom. Each hydrogen atom has one valence electron and the oxygen atom has six valence electrons.	
2 Rearrange the atoms to align the unpaired electrons.	Hydrogen atoms can only form one bond each, so oxygen must be in the middle (H–O–H, not O–H–H).	
3 Move the symbols closer to show the unpaired electrons forming bonding pairs.	Oxygen now has two single covalent bonds and two non-bonding pairs of electrons for a total of eight electrons; a stable octet.	
4 Optional step: Replace the shared electrons with lines.	Usually, shared electrons are replaced with a line for simplicity. All valence electrons should be shown, including the non-bonding pairs. A line represents two bonding electrons.	

If you are given the dot formula, determining the molecular formula is straightforward: count the atoms in the formula and write the quantity of each atom as a subscript number following the element symbol. Table 3.8 shows some common covalent molecules and their formulas.

Table 3.8: Some common covalent molecules and their dot formulas and molecular formulas

Molecule	Dot formula	Molecular formula
Hydrogen	H:H	H_2
Chlorine	:Cl:Cl:	Cl_2
Hydrogen chloride (hydrochloric acid)	H:Cl:	HCl
Carbon dioxide	:O::C::O:	CO_2
Ammonia	H:N:H with H below N	NH_3
Ozone	O=O–O	O_3

Ammonium hydroxide
NH_4OH



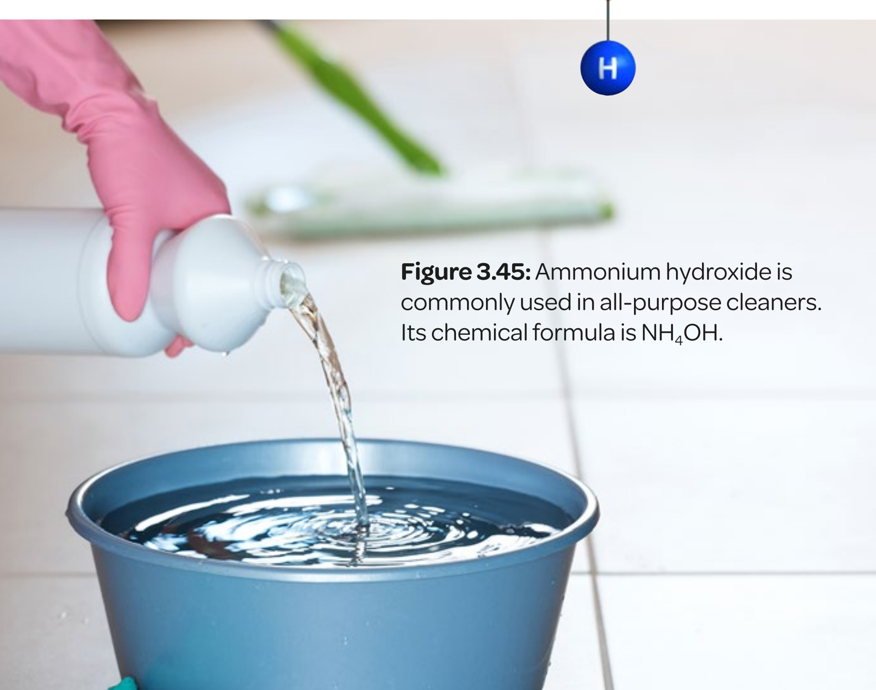


Figure 3.45: Ammonium hydroxide is commonly used in all-purpose cleaners. Its chemical formula is NH_4OH.

Learning Ladder

Materials

1. Classify the following compounds as ionic or covalent.
   a NaCl
   b Methane (CH_4)
   c $Ca(CO_3)$
2. Which of the compounds from Question 1 have covalent bonds? Describe any interesting findings.
3. Select a covalent substance mentioned in this section. Predict its properties based on its use.
4. Greenhouse gases include the covalent compounds carbon dioxide (CO_2), ozone (O_3), water vapour and methane (CH_4). Propose and discuss the properties that covalent compounds might have in common that make them prone to being a greenhouse gas.

Communicating

see page 429

1. List the pros and cons of using dot formulas versus chemical formulas to represent covalent substances.
2. Describe why it might be more efficient to represent a sample of discrete molecules by using digital technologies rather than by hand.
3. Construct the chemical formulas for:
   a carbon monoxide.
   b silicon tetraiodide.
   c dinitrogen trioxide.
   d arsenic pentafluoride.
4. **a** Construct diagrams you could use to show the bonding in the diatomic molecules H_2, I_2, O_2 and P_2 to a group of adults.
   b How would you modify your diagrams to suit an audience of Year 7 students? Provide examples.
5. Evaluate the need for scientists to follow rules when naming covalent substances. Provide examples to support your evaluation.

In context

Suggest where acetylsalicylic acid, ethanol and ammonia are commonly found. Identify their common names and chemical formulas, and describe their purposes.

Success criteria

- I can use dot formulas to show how diatomic molecules are formed by sharing electrons.
- I can name and write chemical formulas for some common covalent substances.

3·10 ▸ Common materials

Learning intention

At the end of this lesson, I will be able to identify types of substances based on their general properties.

Key terms

crystalline solid: a solid with a highly ordered arrangement of particles at the microscopic and macroscopic levels

giant network solid: a continuous network of atoms joined together through covalent bonds (not discrete); also called 'covalent network solid'

Investigation 3.10

Student-designed investigation: properties of common substances, page 504

Content group: Bonding

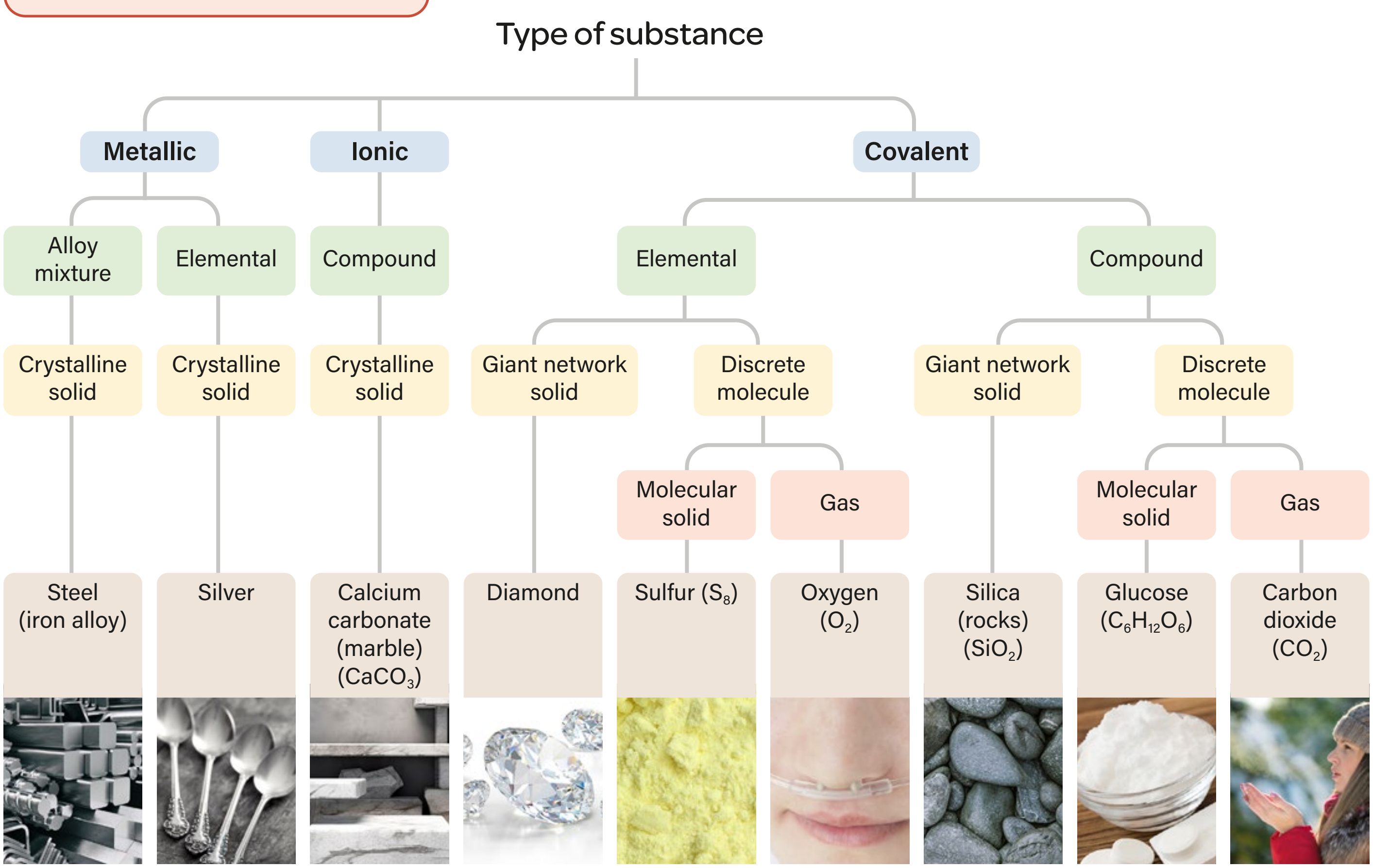
The bonding between atoms determines the type of substance that forms. Ionic, metallic and covalent materials generally have unique properties that help us identify and classify them.

Materials can be classified

Figure 3.46 shows the general classification of substances and the variations of their common forms at room temperature. **Crystalline solids** have highly ordered arrangements of particles and **giant network solids** are made up of a continuous network of atoms.

Substances have identifying properties

The general properties of most substances are listed in Table 3.9 and can be related back to their chemical bonding and structure.



▲ **Figure 3.46:** Classification of substances and some examples

Table 3.9: General properties of metallic, ionic and covalent substances

Property	Metallic substances	Ionic substances	Covalent substances
Melting and boiling points	High	High	Low
Conductivity (electricity)	Good	Conduct when molten or dissolved in water, but not when in a solid state	Not good
Conductivity (heat)	Good conductor	Good insulator	Good insulator
Brittleness	Malleable/ductile	Brittle	Soft and flexible
Lustre	Lustrous/shiny	Form crystalline lattice	Dull
Density	High	High	Low

However, some substances have different properties from those listed in Table 3.9. For example, diamond has an extremely high melting point (4500 °C). This is due to the very strong arrangement of covalent bonds between the carbon atoms that repeat to form a giant network solid, similar to a metallic or ionic lattice.

Properties influence use

The properties of substances determine how we use them. Gold, with its lustre and malleability, is perfect for jewellery. Copper's conductivity and ductility make it ideal for electrical wiring. Magnesium carbonate's ability to neutralise acids makes it useful in antacid tablets, and water's solvent properties are crucial for many industrial processes.

Learning Ladder

Materials

1. Classify the following substances as metallic, ionic or covalent and provide a reason. If you are not sure, make an educated guess.
   a Aluminium foil
   b Sugar ($C_6H_{12}O_6$)
   c Baking soda ($NaHCO_3$)
   d Air
   e Plastic bag
   f Table salt
2. Compare metallic, ionic and covalent materials. Refer to bonding, general properties and examples of common substances. You can use a Venn diagram or similar to organise your ideas.
3. Explain three reasons for making frying pans out of metal, with reference to the properties of metals.
4. Single-use plastics have been banned in many places. Based on what you know about their environmental impacts, propose and describe a property of covalent plastics that is not listed in Table 3.9.
5. Select a substance described in this section that has properties different from what is expected. Investigate and evaluate how it is used in society.

Planning investigations

see page 405

You have been asked to design an investigation to see if the properties of the examples provided in Figure 3.46 match the general properties of metallic, ionic and covalent substances outlined in Table 3.9.

1. **a** Identify five hazards that might be associated with the investigation.
   b Describe ways to minimise the risk of each hazard.
2. **a** State and describe the independent, dependent and controlled variables for your investigation.
   b Construct a results table with the independent variable in the first column and the dependent variable across the top, labelled with units and trials as appropriate.
3. Develop a clear and specific aim for your investigation.
4. Write a step-by-step procedure to address the aim that is detailed enough for a classmate to follow.
5. Explain the type of data collected in your investigation. Discuss how the data collected is reliable in reaching a valid conclusion for your investigation.

In context

Justify the following statement. Use examples of common substances to support your justification.

'Metals are never compounds, ionic substances are always compounds, and covalent substances can be compounds.'

Success criteria

- I can describe the general properties of metallic, ionic and covalent substances.
- I can explain how properties of common substances are related to their uses.

3.11 ► Organic chemistry

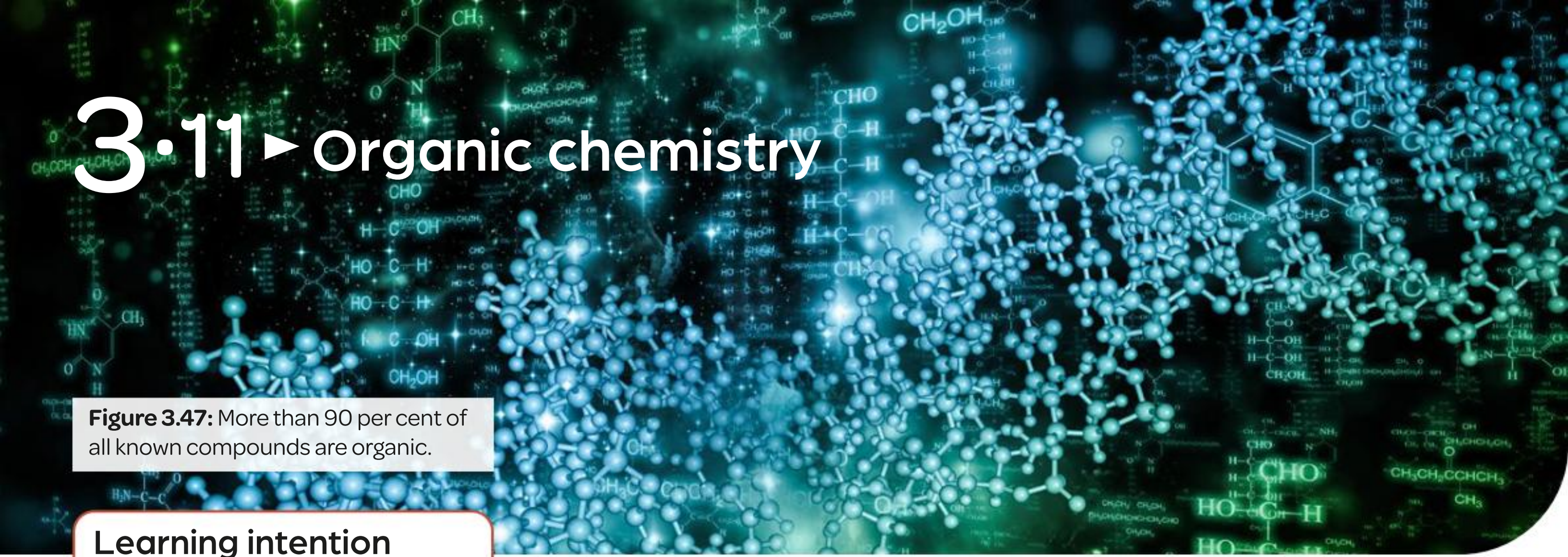


Figure 3.47: More than 90 per cent of all known compounds are organic.

Learning intention

At the end of this lesson, I will be able to distinguish between organic and inorganic compounds.

Key terms

hydrocarbon: an organic compound made up of only carbon and hydrogen atoms

inorganic compound: a substance that does not contain carbon–hydrogen bonds

organic chemistry: the study of carbon-containing compounds

organic compound: a substance that contains carbon, commonly bonded to hydrogen

Content group: Chemistry of organic compounds

The study of carbon-based materials is called organic chemistry. Organic compounds are the foundation of life and include substances such as fuels and oils. They always contain carbon–hydrogen bonds. In contrast, inorganic compounds, such as ionic salts and metals, do not contain carbon–hydrogen bonds.

Carbon can form a variety of structures

Carbon has four valence electrons (Figure 3.48), so to achieve a stable octet it needs four more electrons. It can do this by forming four single covalent bonds (with four other atoms), a mix of double and triple covalent bonds, or carbon chains and rings. This versatility of bonding is why carbon forms the basis of more than 90 per cent of all known compounds. There are at least 10 million different **organic compounds**.

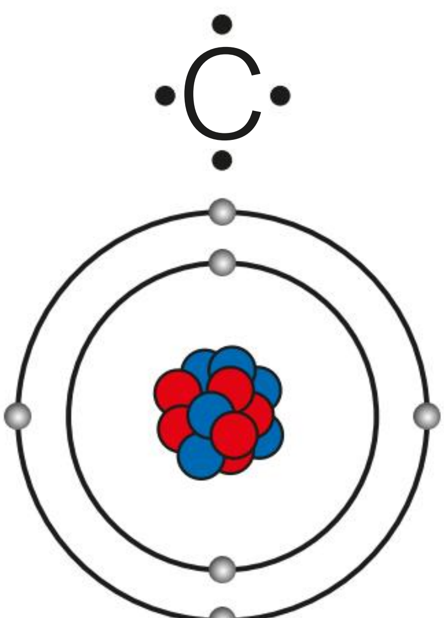


Figure 3.48: Carbon has four valence electrons, which will form four covalent bonds with other atoms.

Hydrocarbons are a type of organic compound

Hydrocarbons are the most basic type of organic compound. They contain only carbon and hydrogen atoms covalently bonded together. Their structure can be described as carbon chains surrounded by hydrogen atoms, as shown in Figure 3.49. Their general properties include:

- odourless/colourless
- low boiling and melting temperatures
- low solubility in water
- poor conductors of electricity
- highly flammable.

Fossil fuels are the main source of hydrocarbons – in particular, crude oil and natural gas. This will be discussed in more detail in Section 3.14.

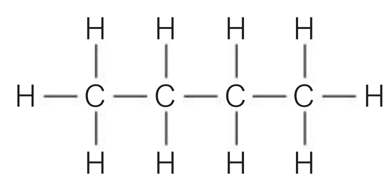


Figure 3.49: An example of a hydrocarbon chain. Each carbon has four covalent bonds, whereas each hydrogen has one.

There are many types of organic materials

Although all organic compounds contain carbon, there is a huge variety in the types of organic materials. All organic compounds must contain carbon and hydrogen, but they can also include oxygen, nitrogen, sulfur or phosphorus, and other elements. Organic substances include:

- food molecules such as simple sugars and complex carbohydrates
- fossil fuels, including oil, coal and natural gas
- many industrial products such as paints and detergents
- synthetic materials such as Lycra®, Gore-Tex® and nylon
- medicines and drugs such as aspirin and caffeine.

Figure 3.50: Caffeine is an organic substance with the chemical formula $C_8H_{10}N_4O_2$.

Each of the above is an area of study in its own right. From exploring food chemistry to understanding fossil fuels, it all comes down to carbon and **organic chemistry**.

However, not all carbon-containing substances are organic. For example, diamond is pure carbon, but because it is only one element, and not a compound, it is classed as inorganic. Any compound that contains carbon but no hydrogen is an **inorganic compound**. Gases such as carbon dioxide and carbon monoxide are inorganic carbon compounds.

Learning Ladder

Materials

1. Classify the following materials as organic or inorganic.
   a Propane gas (C_3H_8)
   b Sodium chloride salt (NaCl)
   c Silver earrings (Ag) **d** Sugar ($C_6H_{12}O_6$)
2. Propose why carbon dioxide is considered to be an inorganic compound, even though it contains carbon.
3. Based on the general properties of hydrocarbons, explain how they might be useful in society.
4. Discuss the impact of a named inorganic compound from this section on the environment, using secondary research as needed.
5. Evaluate the following statement: 'We should not use hydrocarbons because they come from fossil fuels, which are bad for the environment.'

Communicating *see page 429*

1. Propose why it might be beneficial to represent an organic compound using a molecular diagram rather than its name.
2. Describe how digital technologies might help people visualise organic compounds.
3. Construct a series of digital slides to summarise and communicate the information and examples in this section.
4. Once you have completed the 'In context' question below, present your findings to the class in 2–3 minutes, using a presentation mode of your choice.
5. Listen to your peers present their 'In context' findings. Evaluate their findings based on the validity of their sources, and identify one way each of them could improve the validity of their presentation.

In context

There are many subcategories of organic chemistry, including medicinal chemistry, food chemistry and synthetic materials. Select one of these and conduct an online search to find out more about this area of science and how it is linked to organic chemistry. How is it important in society? What types of careers are associated with the subcategory of organic chemistry that you chose? What innovations or inventions have emerged from this area of study?

Success criteria

- I can identify organic and inorganic compounds.
- I can describe the properties of hydrocarbons.

3·12 ▸ Classifying organic compounds

Learning intention

At the end of this lesson, I will be able to classify organic compounds based on distinguishing features.

Key terms

alkane: a hydrocarbon containing only single covalent bonds

alkene: a hydrocarbon containing a double covalent bond

alkyne: a hydrocarbon containing a triple covalent bond

functional group: an atom, a group of atoms or a specific feature that is responsible for the chemical properties of a compound

general formula: a formula that represents the atomic composition of members of a class of compounds

homologous series: a class of compounds with the same functional group and whose members differ by $-CH_2-$

saturated compound: a compound with only single covalent carbon–carbon bonds

unsaturated compound: a compound with at least one double or triple carbon–carbon bond

viscosity: the resistance of a substance to flow or change of shape; high viscosity = low ability to flow (thick)

Content group: Chemistry of organic compounds

It would be impossible to determine the total number of organic compounds that exist on Earth, especially since new ones are being discovered and synthesised every day. Instead, we identify and classify organic compounds into 'families', based on their distinguishing features.

A homologous series is a sequence of compounds in the same family

Organic compounds are classified into 'families', or classes, called **homologous series**. Members within a series differ in the length of their carbon chain, but they all have the same distinguishing feature, such as multiple bonds or how an oxygen or a nitrogen atom is attached to the carbon chain. The common features of series are explained below.

Successive members of a homologous series differ by $-CH_2-$

The difference between one member of the series and the next is one additional carbon and two additional hydrogen atoms – CH_2-. This is true for most homologous series, regardless of the distinguishing feature.

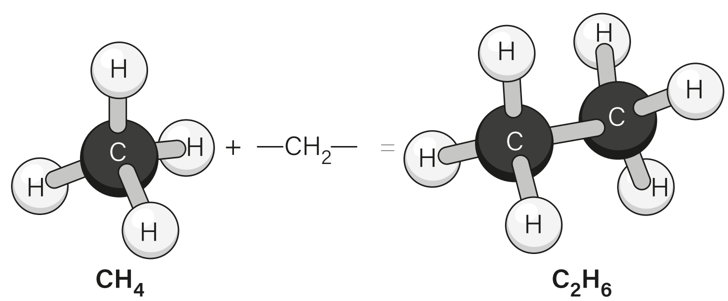


Figure 3.51: These two organic compounds are part of the same homologous series. They differ by one carbon atom and two hydrogen atoms.

Members of the same homologous series can be represented by the same general formula

A **general formula** shows the atomic composition of members of a class of compounds. If the general formula for the series is C_nH_{2n}, n represents the number of carbon atoms, which is then used to determine the number of hydrogen atoms.

If you know the general formula and the number of carbon atoms, you can determine the molecular formula of the compound. For example, for the two compounds shown in Figure 3.51:

Step 1. Determine the general formula.	C_nH_{2n+2}	C_nH_{2n+2}
Step 2. Determine the number of carbon atoms.	1 carbon	2 carbons
Step 3. Replace '***n***' with number of carbon atoms.	$C_1H_{(2\times1)+2}$	$C_2H_{(2\times2)+2}$
Step 4. Solve for the subscript value to determine the number of hydrogen atoms.	CH_4	C_2H_6

Members of the same homologous series have similar yet progressive physical properties

Organic compounds generally have low boiling temperatures. But as they get larger, the forces between molecules get stronger, so the boiling temperature increases. Therefore, successive members of a series have higher boiling temperatures (Table 3.10).

The same trends are observed for other physical properties such as density and **viscosity** (a substance's resistance to flowing easily).

Table 3.10: Boiling points of the first three members of a homologous series

Successive members of a series	Boiling point (°C)
CH_4	–164
C_2H_6	–89
C_3H_8	–1

Figure 3.52: Honey can be described as 'viscous', meaning it is thick and does not flow easily.

Members of the same homologous series have similar chemical properties

The distinguishing feature used to classify compounds into families also gives the compound its chemical properties. Chemical properties include:

- how acidic (high pH) or basic (low pH) the compound is
- the ability to oxidise (react with oxygen)
- the ability to undergo addition reactions (adding more atoms to the carbon chain).

Hydrocarbons with double bonds undergo addition reactions, in which other atoms are added to the double-bonded carbons (see Figure 3.53).

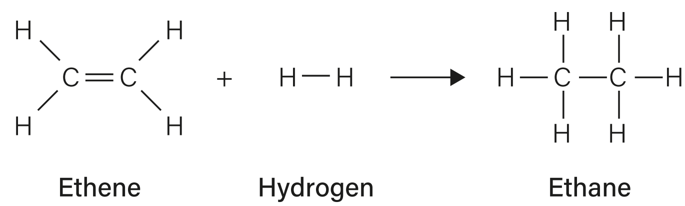
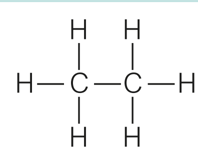
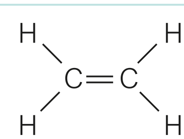
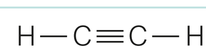


Figure 3.53: If a hydrocarbon has a double bond, other atoms can be added to the carbons of the double bond. In this reaction, hydrogen has added across the double bond.

Hydrocarbons can be classified into three classes

Hydrocarbons can be classified into three classes of straight-chain compounds, based on whether they contain single (**alkane**), double (**alkene**) or triple (**alkyne**) carbon–carbon bonds (see Table 3.11).

Table 3.11: The classes of hydrocarbons are alkanes, alkenes and alkynes

Class	Distinguishing feature	Example
Alkanes	Contain only single covalent bonds	
Alkenes	Contain a double covalent bond	
Alkynes	Contain a triple covalent bond	

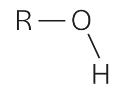
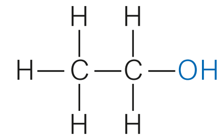
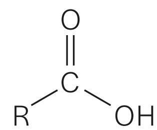
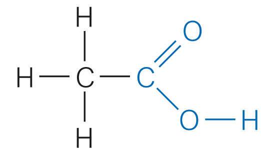
When hydrocarbons do not have any multiple carbon–carbon bonds, the compound is considered to be a **saturated compound**, because no more hydrogen atoms can be added. In contrast, a compound with double or triple carbon–carbon bonds is an **unsaturated compound** because it is possible to add more hydrogen atoms to the double or triple bond.

Figure 3.54: The viscosity of hydrocarbons increases as the length of the carbon chain increases. The chains in petrol are eight carbons long, whereas the chains in bitumen are more than 70 carbons long. So, bitumen is more viscous than petrol.

Functional groups give organic compounds their properties

The distinguishing feature of an organic compound is called its **functional group**. It is what makes the compound behave, or function, in a particular way. For hydrocarbons, the single, double and triple bonds can be considered their functional group because they give the alkanes, alkenes and alkynes different properties. Many functional groups include atoms other than carbon and hydrogen. Table 3.12 describes alcohol and carboxylic acid functional groups.

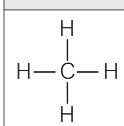
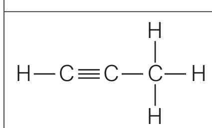
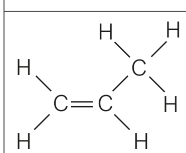
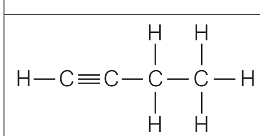
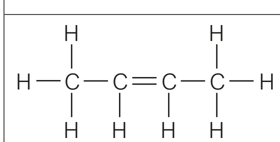
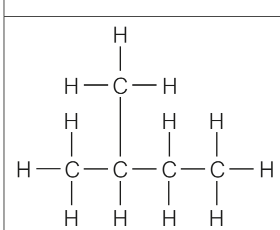
Table 3.12: Alcohol and carboxylic acid functional groups

Class	Distinguishing feature	General structure and formula ('R' represents the rest of the molecule, often a hydrocarbon chain)	Symbol for functional group	Example
Alcohol	An oxygen atom with a single bond to each of a carbon and a hydrogen		-OH	
Carboxylic acid	The carbon at the end of the chain has a double bond to an oxygen, and a single bond to another oxygen and hydrogen		-COOH	

Learning Ladder

Materials

1. Copy and complete the following table to classify the molecules as alkanes, alkenes or alkynes (homologous series), and say whether each is saturated or unsaturated.

Compound structure	Homologous series	Saturated or unsaturated
		
		
		
		
		
		

2. Describe the difference between alkanes, alkenes and alkynes, with reference to their general formulas.
3. Although all hydrocarbons can undergo combustion to release energy, propose why petrol (C_8H_{18}) is a more suitable fuel than hydrocarbons with larger carbon chains.
4. Bitumen is a waste product when fossil fuels (particularly crude oil) are refined. Discuss the environmental pros and cons of using bitumen as a material for constructing our roadways.

Problem-solving *see page 425*

1. Describe a solution used to classify the infinite number of organic compounds that exist.
2. Explain why it might be problematic not to classify organic compounds according to their distinguishing properties.
3. The general formula for alkanes is C_nH_{2n+2}. Use Table 3.11 to help you determine the general formulas for alkenes and alkynes.
4. Propose and discuss any disadvantages of using a systematic approach to classifying organic compounds, especially for more complex molecules with many distinguishing features.

In context

Alcohols and carboxylic acids react with each other to form compounds with an ester functional group (R–COO–R). Where have you heard this word used to describe materials? Conduct an online search to identify the distinguishing properties of esters and their uses in society.

Success criteria

- I can describe the features shared by members of the same homologous series.
- I can differentiate between alkanes, alkenes and alkynes.

3.13 ▸ Naming and representing organic compounds

Learning intention

At the end of this lesson, I will be able to use IUPAC nomenclature to name and draw simple organic compounds.

Key terms

IUPAC: International Union of Pure and Applied Chemistry

locant: a number that indicates the carbon where certain parts of an organic compound are positioned

prefix: letters or numbers placed before the stem of the word

skeletal formula: a shorthand way to represent organic compounds, using only lines and symbols for elements other than carbon and hydrogen

stem: the word in the name of an organic compound that indicates the number of carbons in the longest chain

structural formula: a representation of a compound that shows the structural arrangement of atoms

suffix: a word or letters placed after the stem of the word

Investigation 3.13

Modelling organic compounds, page 506

Content group: Chemistry of organic compounds

There are rules for naming organic compounds so that their unique names can be recognised and understood by scientists all over the world.

IUPAC names include a prefix, stem and suffix

The International Union of Pure and Applied Chemistry (**IUPAC**) has rules for naming organic compounds. The name of an organic compound has three possible parts, as follows:

- **Prefix**: includes the names of any branches of the main chain.
- **Stem**: the number of carbon atoms in the longest continuous chain.
- **Suffix**: the class of compound, which is determined by the functional group.

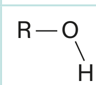
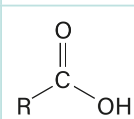
We will only focus on simple organic compounds that require a stem and a suffix. For more complex compounds, you would need to understand how to apply a prefix, but you do not need to know that for this course.

Tables 3.13 and 3.14 show the IUPAC conventions for naming organic compounds with up to eight carbons and containing simple functional groups. It is a good idea to memorise the stem and suffix names.

Table 3.13: Stem names indicating the number of carbon atoms in the longest continuous carbon chain

Number of carbon atoms in longest chain	Stem in IUPAC name
1	meth-
2	eth-
3	prop-
4	but-
5	pent-
6	hex-
7	hept-
8	oct-

Table 3.14: Suffixes indicating the homologous series or functional group present

Class	Functional group	Suffix in IUPAC name
Alkane	–C–C–	-ane
Alkene	–C=C–	-ene
Alkyne	—C≡C—	-yne
Alcohol		-anol
Carboxylic acid		-anoic acid

Organic compounds can be named according to IUPAC rules

In Section 3.12, we learnt about the distinguishing features that are used to classify hydrocarbons, alcohols and carboxylic acids.

The simplest hydrocarbon is methane, CH_4. The stem name 'meth-' tells us there is one carbon in the longest carbon chain, and the suffix '-ane' tells us that it is an alkane.

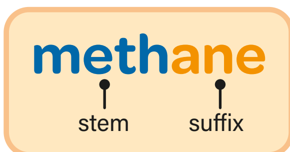
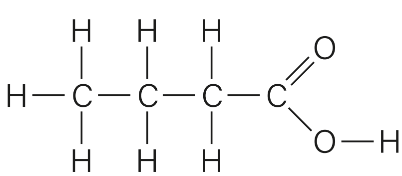


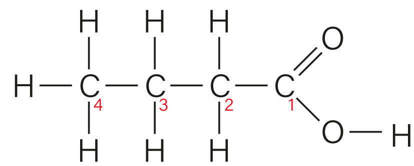
Table 3.15 shows how the successive members of each series are named according to IUPAC rules. Some names have numbers before or in the suffix. This is called a **locant** and indicates which carbon the functional group is connected to.

You will not always have access to tables of names of organic compounds, so it is a good idea to become familiar with stem names and suffixes. The following two examples show you how to name simple organic compounds according to IUPAC rules.

Example 1

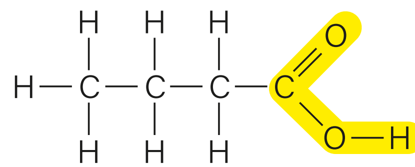


1 Identify the longest continuous carbon chain.
There are four carbons in the chain.



2 Choose the corresponding stem name from Table 3.13.
4 carbons = but-

3 Identify the functional group and choose the suffix from Table 3.14.



It is a carboxylic acid, so its suffix is -anoic acid.

4 Identify the number of the carbon that the functional group is attached to. It should have the lowest number possible.
For carboxylic acids, the carbon of the –COOH group is carbon 1.

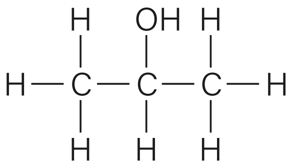
5 Indicate the locant number within the suffix.
(Not applicable for this compound.)

6 Put it all together.
but- + -anoic acid = butanoic acid

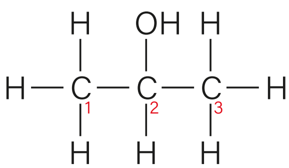
Table 3.15: Names of the first eight members of each homologous series

Number of carbons in longest chain	Alkane	Alkene	Alkyne	Alcohol	Carboxylic acid
1	methane	N/A	N/A	methanol	methanoic acid
2	ethane	ethene	ethyne	ethanol	ethanoic acid
3	propane	prop-1-ene	prop-1-yne	propan-1-ol	propanoic acid
4	butane	but-1-ene	but-1-yne	butan-1-ol	butanoic acid
5	pentane	pent-1-ene	pent-1-yne	pentan-1-ol	pentanoic acid
6	hexane	hex-1-ene	hex-1-yne	hexan-1-ol	hexanoic acid
7	heptane	hept-1-ene	hept-1-yne	heptan-1-ol	heptanoic acid
8	octane	oct-1-ene	oct-1-yne	octan-1-ol	octanoic acid

Example 2



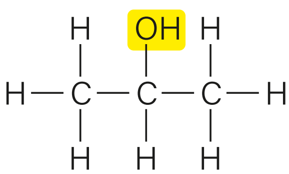
1 Identify the longest continuous carbon chain. There are three carbons in the chain.



2 Choose the corresponding stem name from Table 3.13.

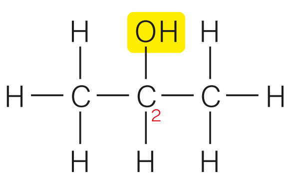
3 carbons = prop-

3 Identify the functional group and choose the suffix from Table 3.14.



It is an alcohol, so the suffix is -anol.

4 Identify the number of the carbon that the functional group is attached to. It should be given the lowest number possible. For example, if the –OH group is on the end of a five-carbon chain, the carbon is numbered 1 rather than 5.



The –OH is attached to carbon 2.

5 Indicate the locant number within the suffix.

-an-2-ol.

6 Put it all together.

prop- + -an-2-ol = propan-2-ol

Note: Steps 4 and 5 can be skipped for alkanes, carboxylic acids and small alkenes, alkynes and alcohols.

Organic compounds can be represented in several ways

The molecular formula shows the total number of atoms in a molecule, but it does not show how the atoms are connected. The **structural formula** shows how all of the atoms are arranged in the molecule, so we can name it accurately. The structural formula can be drawn in full or in condensed form.

A **skeletal formula** is a shorthand way of representing an organic molecule that shows bonds as lines. Each end and junction line indicates a carbon atom, and it is assumed that each carbon atom is attached to enough hydrogen atoms so that each carbon atom has four bonds. If the compound contains atoms other than carbon and hydrogen, then their symbols are included.

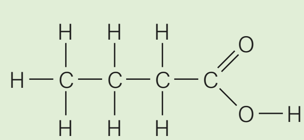
You are not expected to use skeletal formulas as part of the course. But if you know the name of a compound, you should be able to draw the structural formula and condensed structural formula. Use the stem name to determine the number of carbons in the longest carbon chain, then add the distinguishing features indicated by the suffix of the name.

Figure 3.55 shows the different ways that butanoic acid can be represented.

Figure 3.55: The different ways of representing butanoic acid

$C_4H_8O_2$

Molecular formula



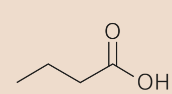
Structural formula

$CH_3CH_2CH_2COOH$

or

$CH_3(CH_2)_2COOH$

Condensed structural formula



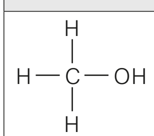
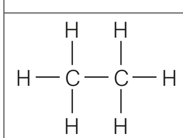
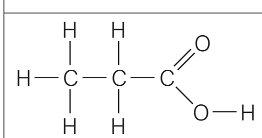
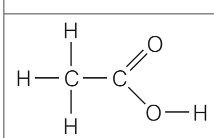
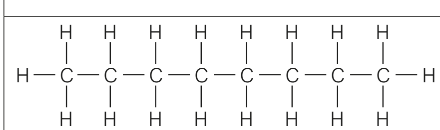
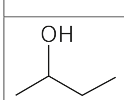
Skeletal formula

Figure 3.56: Organic compounds are often represented using stylised 3D skeletal structures, like the colourful caffeine molecule shown here.

Learning Ladder

Materials

1 Copy and complete the following table to classify the molecules as alkanes, alcohols or carboxylic acids.

Compound structure	Homologous series (class)
	
	
	
	
	
	

2 **a** Name the compounds from Question 1 according to IUPAC nomenclature rules.

b Draw the structural formulas and condensed structural formulas for the following organic compounds:

- **i** Pentane
- **ii** Ethanol
- **iii** Methanoic acid
- **iv** Propyne
- **v** Butan-2-ol
- **vi** Hexanoic acid
- **vii** Hept-3-ene.

c Extension: See if you can draw the skeletal formulas for the compounds in part b.

3 **a** Explain why there is no such thing as methene or ethyne.

b Explain why there is no such thing as pentan-4-ol. Propose the correct name for this compound.

c Draw and name all possible eight-carbon straight-chain alcohols with one –OH functional group.

Communicating

see page 429

1 Propose why it might be beneficial to represent an organic compound using its condensed structural formula rather than its full structural formula.

2 Describe how digital technologies might be used to name more complicated organic compounds.

3 Construct a series of digital slides to summarise and communicate the information and examples in Section 3.13.

In context

Alcohols and carboxylic acids react with each other to form compounds with an 'ester' functional group (R–COO–R). The rules for naming esters are different as compared to simple organic compounds. Conduct an online search to determine how esters are named. How are the names of esters related to the types of alcohols and carboxylic acids that react to form them?

Success criteria

- I can follow IUPAC naming rules to name simple hydrocarbons, alcohols and carboxylic acids.
- I can draw the structural formula of simple organic compounds based on their IUPAC name.

3.14 ► Obtaining and using hydrocarbons

Figure 3.57: Crude oil is made up of different types of hydrocarbons that must be separated into individual components.

Learning intention

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

- describe how hydrocarbons can be separated from crude oil
- describe how the use of hydrocarbons has changed over time.

Key terms

asphalt: a mixture of gravel, sand and bitumen, used for roads

bitumen: the heaviest fraction of crude oil, left over after fractional distillation

condense: to change from a gas to a liquid state

feedstock: a chemical used to support large-scale chemical reactions, usually in industry

fraction: a part of a larger mixture of many parts

fractional distillation: the separation of a mixture into different parts or fractions, according to their different boiling points

fractionating column: a vertical cylinder that decreases in temperature up the column, condensing and separating substances just below their boiling points

Content group: Chemistry of organic compounds

Hydrocarbons are obtained from crude oil and are used to form common products.

Hydrocarbons come from crude oil

Crude oil is a mixture of many hydrocarbons, and needs to be separated into individual hydrocarbon **fractions**, or components, before it can be used. The hydrocarbons range from small, light molecules such as methane (CH_4) to large, heavy molecules such as **bitumen**.

Crude oil is separated by fractional distillation

When crude oil is heated, the different hydrocarbons boil at different temperatures, so they separate out at different points along the **fractionating column**. This process is called **fractional distillation**.

- Crude oil is heated in a furnace to about 350 °C. The oil boils and vaporises, turning the mixture into gases.
- The gases are pumped into a tall fractionating column that is hotter at the bottom and cooler at the top. As the gases rise, they cool down.
- Different hydrocarbons **condense** back into liquids at different heights. The larger, heavier hydrocarbons, which have higher boiling points, condense near the bottom of the column.

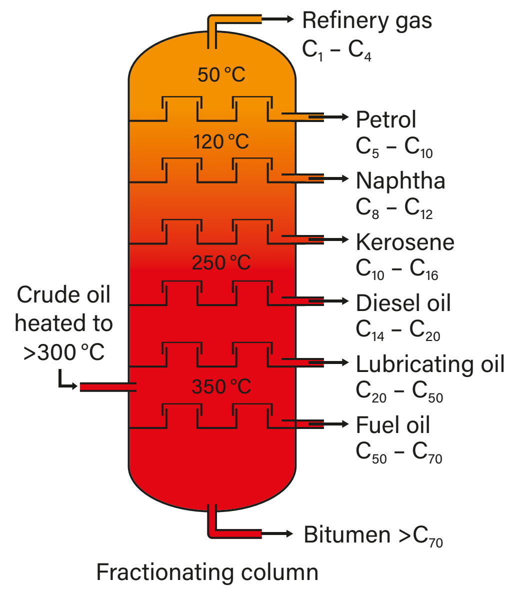


Figure 3.58: The process of fractional distillation vaporises crude oil, then separates the fractions of hydrocarbons based on their boiling temperatures as they move up the fractionating column.

Smaller, lighter hydrocarbons, with lower boiling points, condense towards the top.

- The condensed liquids are collected at various levels of the column. Each fraction contains hydrocarbons with similar boiling points and properties.

Table 3.16: The main fractions obtained from crude oil

Fraction of crude oil	Uses
Refinery gas	Fuel or feedstock for industrial processes, e.g. LPG
Petrol	Fuel for cars
Naphtha	Petrochemicals, e.g. paint solvent
Kerosene	Fuel for jet engines and heating
Diesel oil	Fuel for trucks, buses and some cars
Lubricating oil	To reduce friction in mechanical components
Fuel oil	Fuel for ships and industrial heating
Bitumen	Road surfaces and roofing

Hydrocarbons have a variety of uses

The hydrocarbons separated from crude oil have many uses.

- **Fuels:** Petrol, diesel and kerosene are used to power vehicles, planes and other forms of transportation.
- **Heating and electricity:** Natural gas and fuel oil are used to heat homes and to generate electricity.
- **Polymers and plastics:** Many hydrocarbons are used as raw materials for polymers, which are long chains of carbon molecules that make up plastics. For example, ethene is used to make polyethene, one of the most common plastics.
- **Asphalt:** The heavy fraction called bitumen, left over after distillation, is used to make asphalt for roads.
- **Chemical industry:** Hydrocarbons are used as **feedstocks** for the chemical industry to make a variety of products, including synthetic rubber, fertilisers, solvents and even medicines.

As technology advances and our needs change, scientists are finding new ways to use hydrocarbons, including in more environmentally responsible ways.

Learning Ladder

Materials

1. Identify the fraction to which each of the hydrocarbons below belongs, based on its boiling point:
   - **a** Butane, 0 °C
   - **b** Octane, 126 °C
   - **c** Aeroplane fuel, 190 °C
   - **d** Motor oil, 280 °C
2. Describe the physical trend observed that is related to the increase in boiling point of hydrocarbons.
3. Explain why lubricating oils are more effective than naphtha as engine oils.
4. Discuss the following statement: 'Using fractional distillation to separate crude oil into its components is good for the environment because nothing gets wasted.'

Problem-solving

see page 425

1. Describe the process that is used to separate crude oil into its component fractions.
2. Crude oil was discovered as early as the 4th century BCE but was not used effectively until the 1900s. Explain a scientific problem that people of the 4th century BCE might have had that meant the discovery was not as useful then as now.
3. There is an overlap in the size of carbon chains between the naphtha, kerosene and diesel fractions. Propose what could be done to maximise the purity of the fractions between 250 °C and –120 °C.
4. Discuss the adjustments you could make in the distillation process to increase the yield of petrol from crude oil.

In context

Conduct research into a specific use of a hydrocarbon and how this has changed over time. You may select from the following hydrocarbon products and their uses, or choose a different hydrocarbon: hydrocarbons as fuel for cars, hydrocarbons as engine lubricants; hydrocarbons to make plastics, hydrocarbons to make natural and synthetic clothing materials.

Success criteria

- I can identify hydrocarbon products that are obtained from crude oil.
- I can describe how products derived from crude oil are used in everyday life.

3·15 ▸ Combustion of organic fuels

Learning intention

At the end of this lesson, I will be able to describe the difference between complete and incomplete combustion.

Key terms

biofuel: a fuel derived from biomass such as plants and animal waste, rather than from fossil fuels

combustion: a reaction that involves burning in the presence of oxygen to release heat

exothermic: a reaction that releases energy into the surroundings, causing the temperature to rise

oxidation: a reaction taking place in the presence of oxygen

soot: a black form of carbon formed by incomplete combustion

Investigation 3.15A

Complete and incomplete combustion reactions, page 508

Investigation 3.15B

Combustion of fuels, page 510

Content group: Chemistry of organic compounds

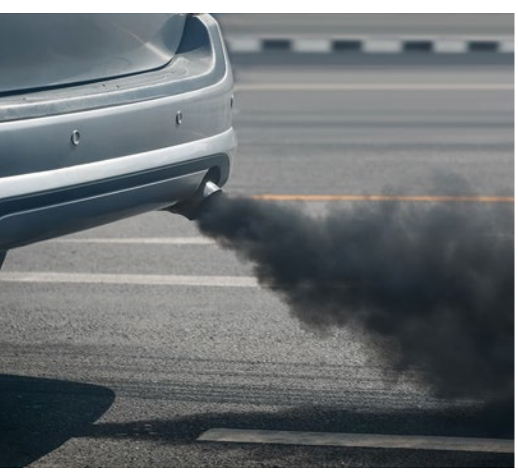


Figure 3.59: Black smoke from your car might indicate that the fuel injector is adding too much fuel, so there is not enough oxygen for complete combustion.

Combustion reactions require a fuel source in the presence of oxygen. The combustion of hydrocarbons can be complete, and different fuels release different amounts of energy.

There are different types of combustion reactions

All combustion reactions are **exothermic**, meaning they release energy. They also all require fuel and oxygen. There are important differences between the various kinds of combustion reactions. Complete combustion happens when a fuel, such as a hydrocarbon, burns in plentiful amounts of oxygen to produce carbon dioxide and water:

Hydrocarbon + oxygen → carbon dioxide + water + energy

When a fuel burns in a limited amount of oxygen, the reaction does not go to completion. The products of incomplete combustion are water and carbon monoxide, or sometimes carbon in the form of **soot**.

Hydrocarbon + limited oxygen → carbon monoxide + water + energy

or Hydrocarbon + limited oxygen → carbon + water + energy

For example, the complete combustion reaction of propane (C_3H_8) requires five molecules of oxygen for every molecule of propane:

Propane + oxygen → carbon dioxide + water

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

If there are only 3.5 oxygen molecules for every molecule of propane, incomplete combustion occurs to produce carbon monoxide and water:

Propane + oxygen → carbon monoxide + water

$$C_3H_8 + 3.5O_2 \rightarrow 3CO + 4H_2O$$

If there are only two oxygen molecules for every molecule of propane, the reaction will produce carbon and water:

Propane + oxygen → carbon + water

$$C_3H_8 + 2O_2 \rightarrow 3C + 4H_2O$$

Soot is black, powdery carbon and is not very useful. Carbon monoxide is a toxic gas, so it is important to ensure that combustion reactions, like those in a car engine, take place in enough oxygen. You can see incomplete combustion happening when a car or truck gives off a lot of

Figure 3.60: Camp stoves use fuels such as ethanol to produce energy for cooking.

black smoke from its exhaust. By varying the amount of oxygen used, you can change the product so that it is less sooty and toxic.

Combustion reactions power the world

The whole world depends on combustion and the energy it releases. Some combustion reactions are obvious, such as fires. We use combustion reactions to provide energy for our daily activities. Cars burn petrol and diesel so that they can transport us from one place to another. We use gas ovens and stoves for cooking. Burning fossil fuels such as coal provides us with electricity to light and warm our homes.

In a **combustion** reaction, most of the chemical energy of the fuel is transformed to heat energy, which increases the temperature of the surroundings. Different types of fuels release different amounts of energy. A popular area of scientific research looks at the efficiency of **biofuels**, which are derived from plants rather than fossil fuels.

Respiration is a combustion reaction

Respiration is a natural process that occurs constantly in all living cells. It is a biochemical reaction that uses glucose ($C_6H_{12}O_6$) as the organic fuel and oxygen that we breathe in to produce the carbon dioxide, water and energy we need for survival.

Learning Ladder

Materials

1. Classify the following fuels as organic or inorganic.
   - **a** Methanol (CH_3OH)
   - **b** Hydrogen gas (H_2)
   - **c** Ammonia (NH_3)
   - **d** Butane (C_4H_{10})
2. Describe the combustion of an organic fuel with reference to the reactants and products.
3. Compare complete and incomplete combustion of organic fuels with reference to the reactants, products and conditions.
4. Some activist groups claim that biofuels produce more carbon dioxide than traditional fuels. If this were true, discuss the environmental pros and cons of using biofuels over traditional fuels.

Planning investigations

see page 405

Read the aim, materials and method of Investigation 3.15A on page 508.

1. **a** Identify items in the materials list that are potentially hazardous.
   b Describe ways to minimise the risk.
2. **a** Identify the:
   - **i** independent variable (what you are changing)
   - **ii** dependent variable (what you are measuring)
   - **iii** controlled variables (what stays the same).

   b Propose ways to improve the controlled variables that would improve this investigation.
3. Propose two alternative aims for this investigation (one for Part A and one for Part B) that would align with the content in this section.
4. Discuss the reliability, validity and ethicality of this investigation. Propose ways to improve any of these areas.
5. Propose two more types of data you could collect for this investigation that would improve the reliability of the results. Give reasons to support your response.

In context

Conduct research and provide a summary of how biofuels are being produced and used to replace traditional fuels. Assess the use of these fuels in terms of their output and efficiency.

Success criteria

- I can identify examples of how combustion reactions are used every day.
- I can compare complete and incomplete combustion.
- I can explain the role of organic compounds in combustion reactions.

3·16 ▸ Making polymers

Learning intention

At the end of this lesson, I will be able to identify the raw materials used to make polymers.

Key terms

addition polymerisation: a reaction in which alkenes join together at the carbon–carbon double bond to form organic polymers

monomer: a small molecule that bonds together in a repeating pattern to form large polymers

polyethylene: the common name for the most widely used plastic; IUPAC name 'polyethene'

polymer: a long-chain molecule (usually carbon-based) made up of many small repeating units

polymerisation: a reaction in which monomers combine chemically to form long-chain molecules

synthesise: make something new by combining smaller parts

synthetic: made by humans by non-natural methods

Investigation 3.16

Polymers in the environment, page 512

Content group: Polymers

Polymers are large molecules made from repeating smaller units called **monomers**. They come from renewable and non-renewable resources and form the basis of many everyday materials such as plastics, rubber and fibres. There are different methods for making polymers, and different ways to use them. From clothing and packaging to medical equipment, polymers are essential for modern life as we know it. Understanding the origin of polymers helps us appreciate the connection between finite resources and the everyday products we rely on.

Crude oil is a raw material used to make polymers

Humans have used natural polymers for thousands of years. For example, latex rubber and cotton (cellulose) can be harvested directly from plants.

Figure 3.61: Latex rubber is a natural polymer that, like sap, comes from trees.

Our ability to make **synthetic** polymers from natural resources such as crude oil and natural gas has expanded the variety of materials available for use in modern society. Crude oil and natural gas are rich in hydrocarbons. The hydrocarbons are processed to make monomers, which are used to **synthesise** polymers. The process of extracting the raw materials and converting them into monomers is the first step in making polymers.

Monomers can be added together to form polymers

Making polymers is called **polymerisation**, which involves chemical reactions that link monomers together to form long chains.

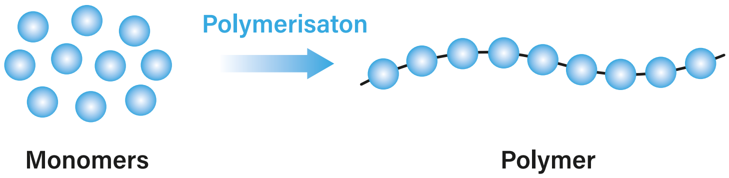


Figure 3.62: Monomers combine to form polymers.

A common method is **addition polymerisation**, where alkenes are added together in a chain reaction to form a polymer. The carbon–carbon double covalent bond breaks and forms single bonds, connecting the monomers together.

The simplest alkene, ethene, serves as a monomer to form polyethene (Figure 3.63). Polyethene is the IUPAC name for the polymer, but this material is commonly known as **polyethylene**, the most widely used plastic in the world.

Although there are no double bonds in the polymer, the name keeps the suffix '-ene' because polymers are named after their monomers, according to IUPAC nomenclature.

The carbon 'backbone' of polymers is made up of the carbons that were double bonded to each other in the monomer, while the rest of the molecule forms branches off the main chain. For example, when the monomer but-1-ene undergoes polymerisation, the first and second carbons form the polymer chain, and the third and fourth carbons become branches, alternating along the chain. Figure 3.64 shows how addition polymerisation is commonly represented as a chemical equation using structural formulas for the monomer but-1-ene and the polymer polybut-1-ene.

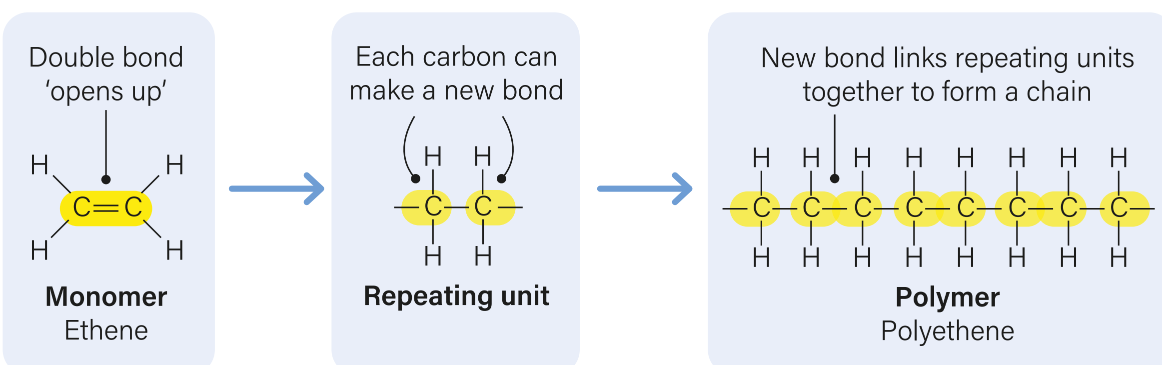
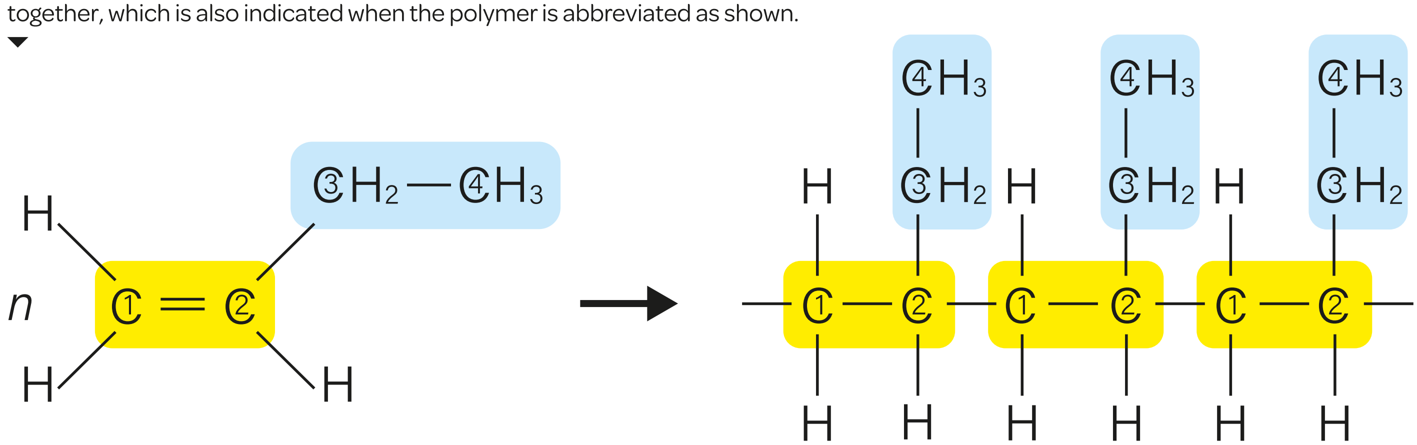


Figure 3.63: The formation of polyethene from the monomer ethene

Figure 3.64: The addition polymerisation reaction of but-1-ene to form the polymer polubut-1-ene. Note: '*n*' represents the number of monomers added together, which is also indicated when the polymer is abbreviated as shown.



There are many forms of polyethylene

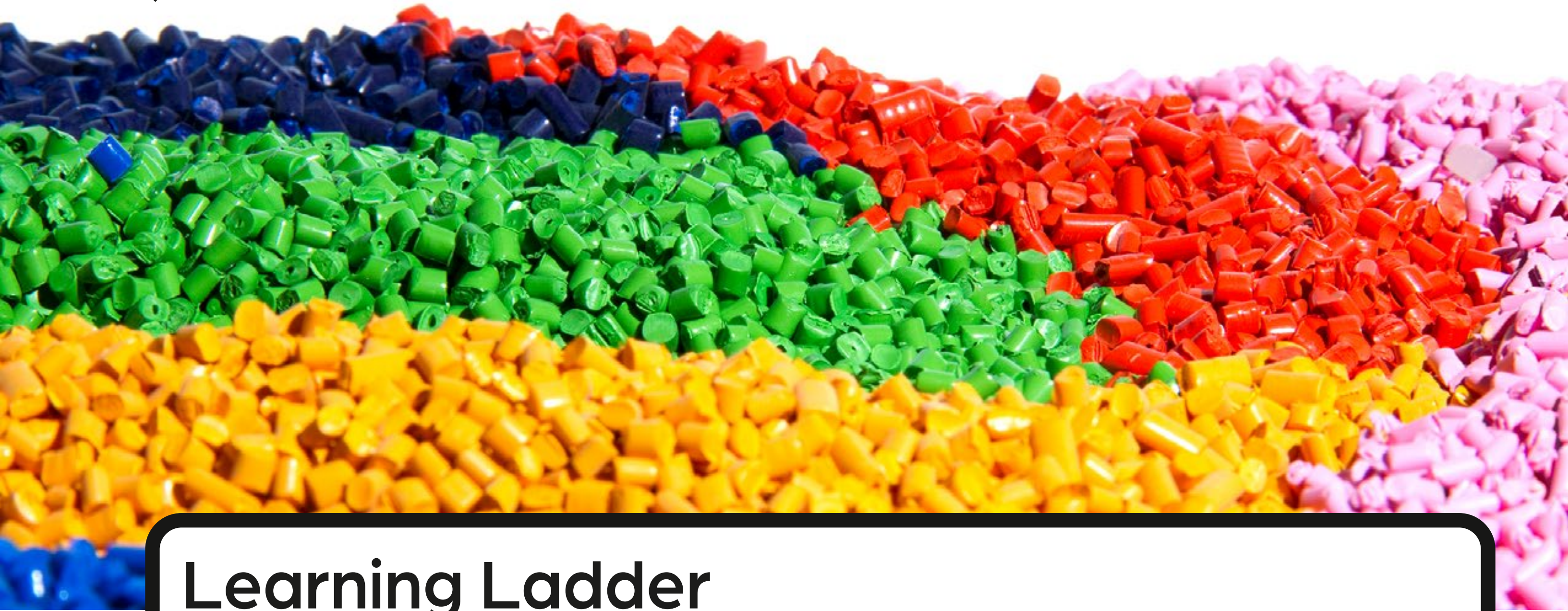
Polyethylene is a highly versatile polymer that comes in different forms. The most common are low-density polyethylene (LDPE) and high-density polyethylene (HDPE).

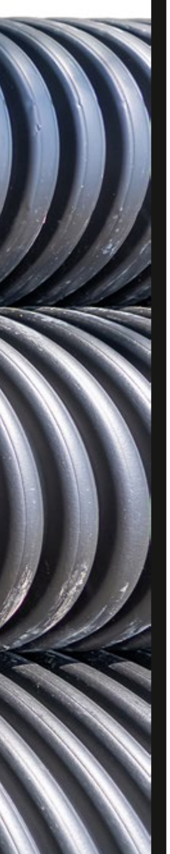
LDPE is made by polymerising ethene under high pressure, resulting in a polymer with a flexible, soft structure. It is used in plastic bags, squeeze bottles and food wrap because it is pliable and lightweight. HDPE is produced under lower pressure and has a more rigid and dense structure. As a result, HDPE is stronger and more durable, ideal for milk jugs, water pipes and plastic crates.

Even though LDPE and HDPE are made from the same monomer, their different production processes result in distinct properties, allowing polyethylene to be used in a wide range of applications.

Figure 3.65: LDPE and HDPE have different degrees of branching, which is why their properties and recycling classifications are different.

Figure 3.66: Small plastic pellets called 'nurdles' can be used to make a variety of plastic products.

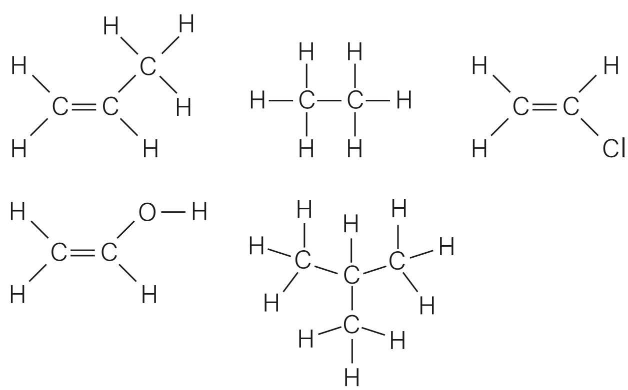




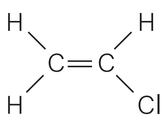
Learning Ladder

Materials

1. Identify which of these monomers can undergo addition polymerisation.



2. **a** Use diagrams to show how the monomer below (chloroethene) can undergo addition polymerisation to form polychloroethene. Include three repeating units in your polymer diagram.



   b Compare the structure and bonding of monomers and polymers, with reference to chloroethene.

3. With reference to LDPE and HDPE, explain how the conditions during a polymerisation reaction can affect the characteristics of the product. Discuss how this might be related to common plastics.

4. Polyethene plastics can take hundreds of years to break down. Using specific examples, discuss how this could be beneficial or detrimental to the environment, depending on the plastic product and its use.

Planning investigations

see page 405

Imagine you are conducting an audit of the types of polymers in the science laboratory and what they are used for.

1. Identify any hazards and describe the steps you would take to minimise risks associated with each hazard.
2. An audit is not a typical form of investigation. Discuss the variables involved in the audit, including how they might be different from the variables involved in a scientific investigation.
3. Propose an overall aim of conducting the audit.
4. Discuss the ethical implications of evaluating the types of equipment and chemicals in the school's laboratory and how they could be minimised.

In context

Condensation polymerisation is another method of synthesising polymers such as nylon, polyester and even proteins. Select one of these polymers and conduct an online search to determine its monomer unit. Describe the difference between addition polymerisation, and condensation polymerisation and discuss the importance of condensation polymerisation.

Success criteria

- I can describe the process of addition polymerisation, particularly the synthesis of polyethene.
- I can compare LDPE and HPDE.

3.17 ▸ The properties of polymers

Learning intention

At the end of this lesson, I will be able to describe the properties of a range of polymers.

Key terms

biodegradable: can be broken down (e.g. by bacteria)

cross-links: chemical bonds that join polymer chains to one another

inert: chemically unreactive

plasticise: to soften a polymer by adding lubricating chemicals, resulting in a more flexible polymer

PVC: polyvinyl chloride

thermoset: a polymer with cross-links; chars when heated instead of melting

vulcanised rubber: synthetic rubber that has been modified from its natural form to include cross-links

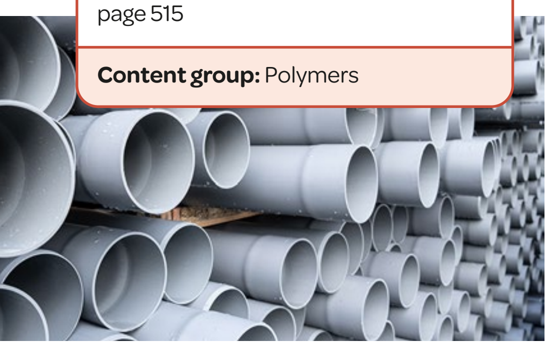
Investigation 3.17A

Biodegradability of packaging, page 513

Investigation 3.17B

Properties of 'Ghostbuster' slime, page 515

Content group: Polymers



▲ **Figure 3.67:** PVC piping is rigid, whereas plasticised PVC forms flexible yet strong sheets, used in containers for medical fluids.

Polymers have become an essential part of everyday life because their useful properties can be altered or manipulated.

Polymers have a range of properties

The properties of polymers can vary widely, depending on the type of polymer and how it is synthesised. In general, polymers have the properties outlined in Table 3.17.

Table 3.17: Properties of polymers

Property	Details and examples
Strength	HDPE is particularly strong and is used for plastic crates and piping.
Durability	Polyvinyl chloride (**PVC**) is used in piping because it can withstand harsh conditions over long periods of time.
Flexibility	LDPE can be rolled into sheets and used as food wrap.
Low reactivity	Addition polymers only contain single bonds, so they are generally **inert** (unreactive). Polyethylene containers can store corrosive substances such as acids.
Low thermal conductivity	Polypropylene is used in carpet and clothing fibres because it provides thermal insulation.
Low electrical conductivity	PVC piping is used as a covering for electrical wires because it does not conduct electricity.

The properties of polymers can be altered

During polymerisation, conditions such as temperature and pressure are carefully controlled. By changing the starting monomers or the reaction conditions, scientists can control the characteristics of the final polymer, such as flexibility, strength or heat resistance. For example:

- LDPE: High-pressure conditions increase branching, which creates more space between chains, decreasing density.
- HDPE: Low-pressure conditions produce more linear polymer chains, allowing the chains to pack more tightly together, increasing density.

Polymers can also be **plasticised** – softened by adding lubricating chemicals so that the polymer chains slide past each other more easily. PVC has very different uses, depending on whether it has been plasticised (Figure 3.67).

Adding **cross-links** to polymers has the opposite effect to adding plasticisers. Cross-links introduce chemical bonds from one chain to another, causing rigidity between chains. Synthetic, or vulcanised, rubber is a **thermoset** polymer; it cannot be melted into a liquid state. Natural rubber has desirable properties, but it does not last long.

Vulcanised rubber has covalent cross-links, which significantly increases the durability of rubber. Without vulcanised rubber, car tyres could not withstand the heat created by friction between the wheels and the road.

Polymers without cross-links are described as thermoplastics, meaning they can be melted down and remoulded as needed.

Polymers are used in everyday life

Polymers have many applications:

- Polyethene is used in plastic bags, containers and even bulletproof vests, due to its strength and durability.
- Polystyrene is used in packaging materials such as foam peanuts and insulation, due to its light weight and insulating properties.
- Plasticised PVC and similar polymers are used in intravenous bags and tubing because they are flexible, durable and safe for medical use.
- Polycarbonate is critical in technology, where it is used to make compact discs and eyeglass lenses because of its clarity and impact resistance.

Biodegradable polymers break down naturally over time, reducing their environmental impact.

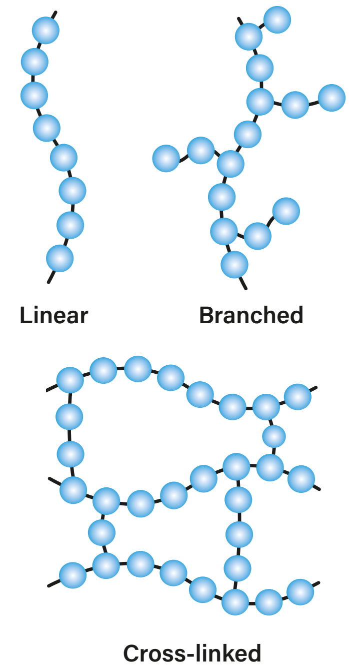
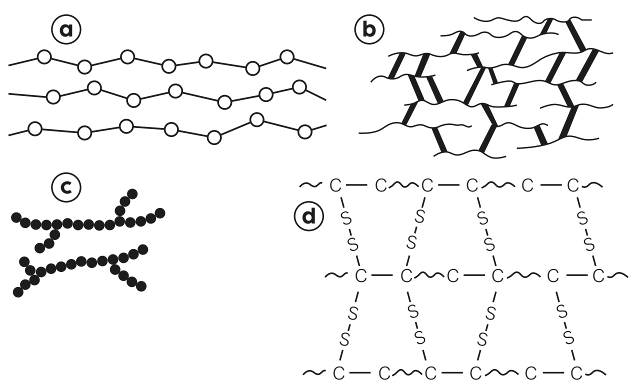


Figure 3.68: The structure of the polymer chain contributes to its properties.

Learning Ladder

Materials

1. Classify the following polymers as thermoplastics or thermosets.



2. Describe the difference between PVC piping and plasticised PVC, with reference to properties and examples.
3. Compare plasticisers and cross-links. Use examples to support your response.
4. Propose and discuss a type of polymer that is 'good' for the environment. Include new terminology and reference to bonding and properties in your response.
5. Propose and evaluate what type of plastic filament is used in 3D printing; thermoplastic, thermoset or both.

Problem-solving

see page 425

1. Propose three alternatives to using single-use plastic shopping bags.
2. Explain a problem for which polymers were the solution. Use specific examples, including new terminology.
3. Determine which type of plastic, thermoplastic or thermoset, would be most appropriate for the following products. Provide a reason for your response.
   a Saucepan handle
   b Single-use water bottle
   c Microwave/freezer-safe food container
   d Lego®
4. Creating vulcanised rubber was a solution to the problem of using natural rubber at high temperatures. Assess this solution in terms of any new problems that may result.

In context

Investigate online how different types of polymers, particularly thermoplastics and thermosets, are recycled and/or reused. Summarise and share your findings with a classmate.

Success criteria

- I can describe ways that the properties of polymers can be altered.
- I can link the properties of common polymers to their uses.

3·18 ▸ Bioaccumulation of microplastics

Learning intention

At the end of this lesson, I will be able to explain how microplastics accumulate in the environment.

Key terms

bioaccumulation: the build-up of chemicals such as microplastics in the tissues of living organisms

biomagnification: increasing concentrations of chemical toxins in organisms up the food chain

microbeads: a type of microplastic with a specific function for scrubbing or exfoliating

microplastics: tiny plastic particles from the physical breakdown of larger plastics

Content group: Polymers

▲ **Figure 3.69:** Microbeads are used in cosmetics and even in toothpaste!

The build-up of plastics in the environment affects ecosystems and human health. Plastics accumulate in food chains, where they can harm marine life and pose risks to humans.

Plastic breaks down into microplastics

Microplastics are tiny plastic particles, typically less than 5 millimetres in size. They either form from the breakdown of larger plastic products or are directly released as small particles, such as **microbeads** in cosmetics. Microplastics are made from various polymers, such as polyethylene and polypropylene, which are durable and resist breaking down.

Microplastics accumulate in food chains

Microplastics escape into the environment through stormwater run-off, improper disposal of plastic waste, and the wearing down of larger plastic debris in oceans and on land. Microplastics are found almost everywhere: in the air, in drinking water, and even in fruits and vegetables. They are particularly problematic in marine environments, where they can be ingested by a wide range of organisms, from tiny plankton to large fish and seabirds.

Because they do not easily break down, microplastics persist in the environment for long periods, accumulating in the tissues of living organisms over time. This is called **bioaccumulation**.

Microplastics accumulate in the bodies of predators that consume smaller organisms. The concentration of microplastics increases in organisms higher up the food chain as smaller fish are eaten by larger predators or by humans. This process is known as **biomagnification** (Figure 3.70).

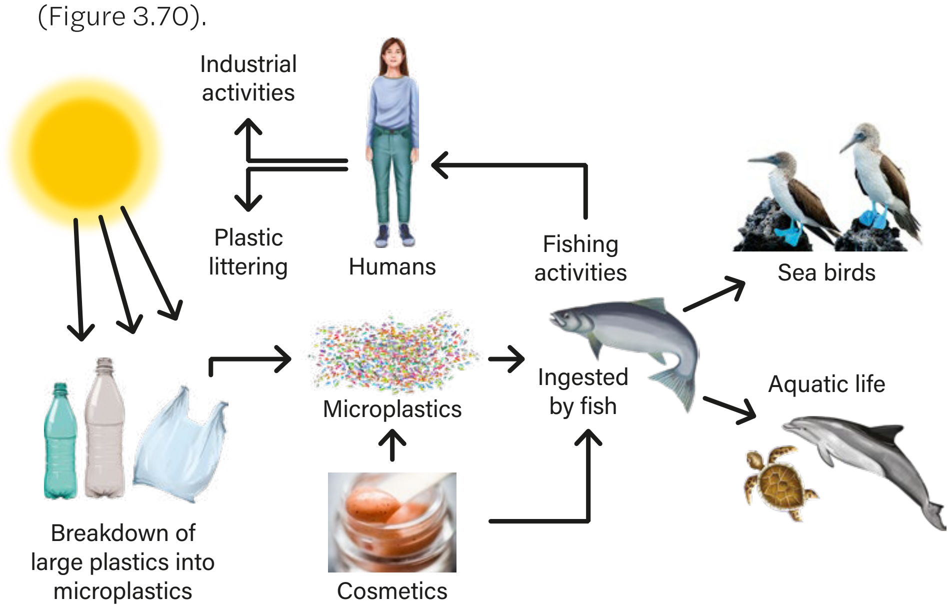


Figure 3.70: ▸ The bioaccumulation of microplastics

Bioaccumulation of microplastics is harmful

When fish ingest microplastics, the particles can damage their digestive system, reduce their feeding behaviour, and even alter their reproductive functions. In some cases, the chemicals associated with microplastics, such as plasticisers and other toxic additives, leach out into the tissues of these organisms, potentially causing further harm.

Humans ingest microplastics when they consume seafood that contains them. The long-term health effects of microplastic ingestion in humans are still being studied, but there is concern that these particles could cause inflammation, toxicity or other health issues.

Bioaccumulation of microplastics affects the environment

We can study real-world examples to better understand the impacts of microplastic pollution and the importance of taking action to reduce it.

The North Pacific Gyre – commonly known as the Great Pacific Garbage Patch – is an area of ocean notorious for its high concentration of plastic debris, including microplastics. Researchers have found that marine organisms in this region, including fish, birds and sea turtles, have ingested large amounts of microplastics. The ingestion of these plastics has been linked to negative health outcomes, such as malnutrition, internal injuries and exposure to toxic chemicals.

Scientific studies indicate that corals in the Great Barrier Reef are ingesting microplastic, mistaking it for food. This damages the coral's digestive tissues, blocking their ability to absorb nutrients effectively. Over time, this can weaken the corals, making them more susceptible to disease and reducing their growth and reproduction rates, and further stressing these vulnerable ecosystems. These harmful effects of microplastics on the Great Barrier Reef highlight the urgent need for global efforts to reduce plastic pollution and to protect one of the world's most vital and biodiverse ecosystems.

Learning Ladder

Materials

1. Classify the following statement as true or false: 'Synthetic polymers will not accumulate in the environment.'
2. With reference to properties and bonding, describe why plastics accumulate in the environment.
3. Explain how microplastics bioaccumulate in the food chain, with reference to specific examples.
4. **a** Discuss the specific impacts of the bioaccumulation of microplastics on the Great Barrier Reef.
   b Propose how the circumstances of this case study might have an impact on your life.
5. **a** Conduct research to learn about rinse-off cosmetics that contain microbeads.
   b Evaluate the decision to ban these products from 2022.

Communicating

see page 429

Complete the 'In context' task below.

1. Propose four different ways you could present your findings to your peers.
2. Use a digital technology of your choice to organise your findings.
3. Construct a digital presentation of your choice (e.g. PowerPoint, Presi, Canva). Be sure to provide references for the sources that inform your presentation.
4. Modify your presentation so it can be communicated to a small group of Year 7 students.

In context

Conduct research to explore a specific case study that highlights the harmful impacts of bioaccumulation of microplastics in the environment. Choose from the following, or find one of your own: Mediterranean Sea, impact of landfills, Thames River (UK), agricultural soils in Europe, San Francisco Bay (United States), Arctic Sea Ice, Lake Victoria (Africa), German forests. Document the sources you use to gather information.

Success criteria

- I can identify environmental impacts of the bioaccumulation of microplastics.
- I can discuss specific examples of bioaccumulation of microplastics in the environment.

3·19 ▸ Materials in context

Learning intention

At the end of this lesson, I will be able to assess the environmental impacts of materials that are being used as alternatives to plastics.

Key terms

bioplastic: a plastic made from a biological material

PLA: polylactic acid; a bioplastic polymer made from corn or sugar

Investigation 3.19

Comparing drinking straws, page 517

Content group: Materials in context

Figure 3.71: Many toys that were once made of wood are now made of plastic, which is more colourful but is a non-renewable material.

For many years, fossil fuels have been used to make plastics. But fossil fuels are a limited resource that take millions of years to form and will eventually run out. Scientists are researching ways of producing and testing materials that will be better, longer lasting and easier to use. But we need to understand the impacts of these alternatives.

Plastics are useful but not environmentally friendly

Plastics are very useful but are made from petroleum, a non-renewable resource. The production of plastics releases carbon dioxide into the atmosphere, which contributes to global warming. When plastics were first made, they were intended to last for a long time. This is good while the products are being used, but not when they are no longer needed. Many plastics can take thousands of years to fully break down in the environment. If not properly disposed of, plastics pollute rivers, seas and beaches, killing fish and marine organisms. Scientists have had to come up with ways of making plastic more environmentally friendly.

Bioplastics are more environmentally friendly

Bioplastics are a type of plastic invented about 100 years ago. They are made from natural plant polymers such as starch and cellulose, from corn and sugarcane. The starch is broken down into glucose, which is made into lactic acid. Many molecules of lactic acid are joined to make the polymer polylactic acid (**PLA**), which can be used in bioplastics. Bioplastics are used in food containers, grocery bags, some cutlery and food packaging. They have many uses in electronics, farming, clothes making and health care.

Many bioplastics are biodegradable: they break down quickly in the environment. Bacteria and fungi in industrial composters can quickly break down these plastics. The bioplastics absorb water, swell up and break into small pieces that bacteria can easily digest – sometimes in just a few weeks. Even if not properly composted, bioplastics have less environmental impact than plastics formed from petroleum. If PLA is burned, it does not give off toxic fumes. If it ends up in a landfill, it breaks down a lot faster than traditional plastics.

There are many other benefits of bioplastics. They are cheaper and take less energy to make, and they produce less greenhouse gas emissions. They are also easier to recycle into other products.

Figure 3.72: Bioplastic wrapping breaks down much faster than traditional plastics.

Plastic alternatives have environmental impacts, too

Bioplastics have disadvantages and scientists are still working to improve them. For example, many bioplastics cannot be broken down in backyard compost heaps, so bioplastics may still end up in landfill. Additionally, since bioplastics are made from plants such as corn, it means that those plants cannot be used as food, and any chemicals used on those plants can make their way into the bioplastic. This can have unpredictable effects on both the bioplastic and the people who use it.

Table 3.18: Possible environmental impacts of using alternatives to plastic drinking straws

Material	Intended use	Possible implications and impacts
Paper	Single use	▪ Break down while being used ▪ More than one used per drink ▪ Require trees as resource
Metal	Reusable	▪ Very cold on the lips, especially for frozen drinks ▪ Treated like a single-use straw, wasting metal resources
Silicon	Reusable	▪ Large circumference, so may not please the consumer ▪ Treated like a single-use straw, wasting silicon resources and increasing landfill waste
PLA bioplastic	Single use	▪ Plants used for bioplastic rather than as food ▪ Limited shelf-life

Other alternatives to fossil fuel–based plastics are being explored. Many types of single-use plastics have recently been banned in Australia, so alternative materials such as paper, PLA, silicon and metal straws are now commonly used. But even these alternatives can have negative impacts on the environment (Table 3.18).

Learning Ladder

Materials

1. Identify two advantages and two disadvantages of straws made from paper.
2. Making plastics and polymers from fossil fuels is not sustainable. Describe why, with reference to properties and bonding.
3. **a** Order the following materials from 'best' to 'worst' as an alternative to plastic in thongs (footwear): silicon, leather, hemp, bioplastic, wood, metal, natural rubber.
   b Construct a table to explain your response based on the properties, practicality and environmental impact of each alternative.
4. Discuss why it might not be appropriate to use bioplastics to store food for long periods of time.
5. **a** Explain how PLA is made and why it is biodegradable.
   b Evaluate whether PLA is an appropriate material to replace traditional plastics.

Problem-solving

see page 425

1. If there are no environmentally friendly alternatives to plastic straws, propose a logical solution to this problem.
2. **a** Describe what caused scientists to introduce bioplastics.
   b Explain the effects of introducing bioplastics, with reference to specific examples.
3. Discuss the benefits and drawbacks of supporting scientists in their research into new materials.

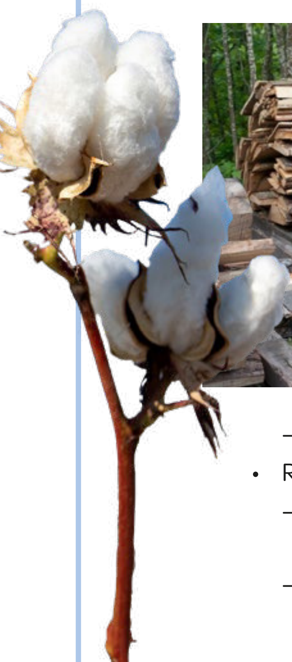
Success criteria

- I can describe the environmental impacts of using plastics derived from fossil fuels.
- I can discuss bioplastics and other materials as alternatives to traditional plastics

► Materials summary

Resources

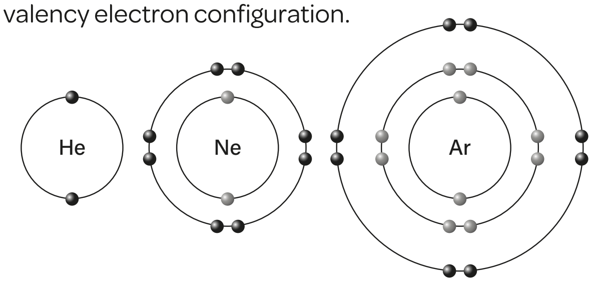
- Resources can be natural, renewable or non-renewable (finite).
  - Wood and cotton are natural renewable resources.



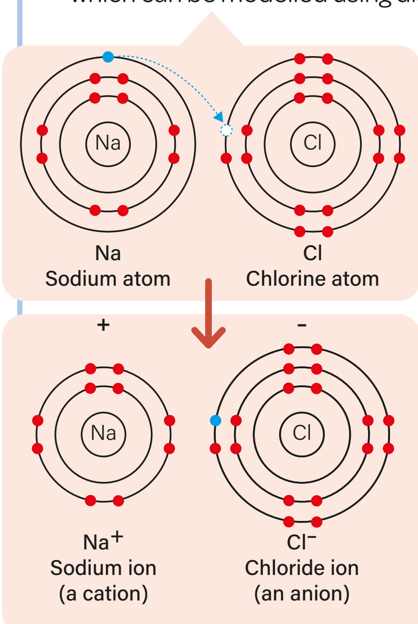
  - Fossil fuels are non-renewable.
- Resources are used to make new materials.
  - Fossil fuels are extracted from the ground and used for many purposes.
  - Rocks and minerals in Australia are mined to extract metals.
- First Nations Peoples used minerals as tools and pigments.

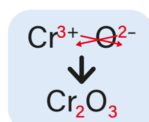
- Extracting and using resources has impacts on the environment, for which scientists find solutions.

- There are three main types of chemical bonding:
  - **metallic bonding:** metals bonded to other metals
  - **ionic bonding:** metals bonded to non-metals
  - **covalent bonding:** non-metals bonded to non-metals.
- Atoms form bonds by losing, gaining or sharing electrons to become stable, achieving a noble gas valency electron configuration.



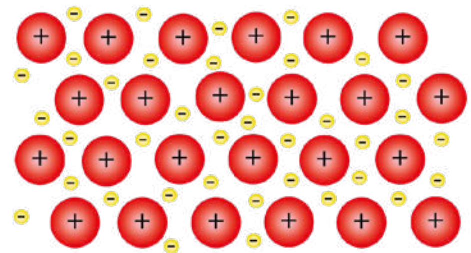
- Ionic bonds are formed between a cation and an anion, which can be modelled using diagrams.



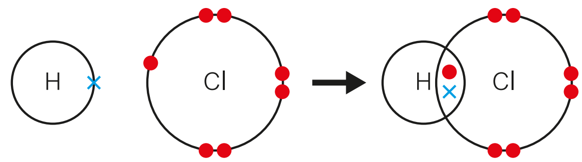


- The swap-and-drop method can be used as a tool for constructing chemical formulas for ionic compounds, e.g. chromium(III) oxide.

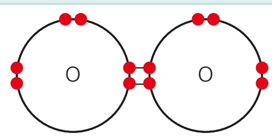
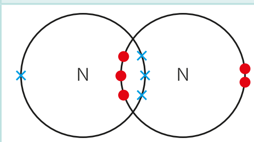
- The metallic bonding model shows fixed rows of cations surrounded by a sea of delocalised electrons.



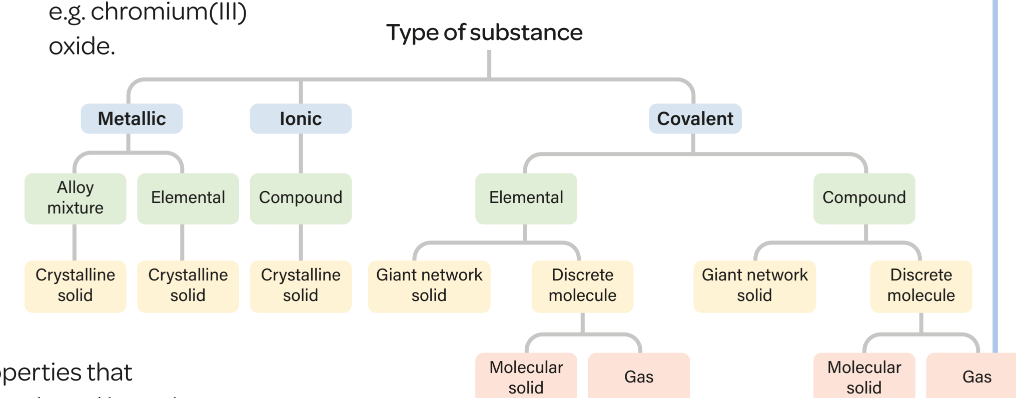
- A covalent bond is a shared pair of electrons between two atoms.



- Most non-metals can form covalent bonds with themselves to form diatomic molecules.

Oxygen (O_2)	Nitrogen (N_2)
	

- All materials can be classified as metallic, ionic or covalent, which can be related back to their bonding.

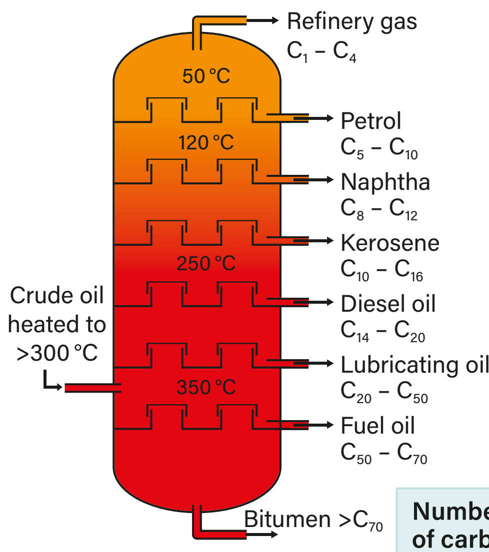


- Substances have identifying properties that influence how they are sourced and used in society.

Property	Metallic substances	Ionic substances	Covalent substances
Melting and boiling points	High	High	Low
Conductivity (electricity)	Good	Conducts when molten or dissolved in water, but not when in a solid state	Not good
Conductivity (heat)	Good conductor	Good insulator	Good insulator
Brittleness	Malleable/ductile	Brittle	Soft and flexible
Lustre	Lustrous/shiny	Form crystalline lattice	Dull
Density	High	High	Low

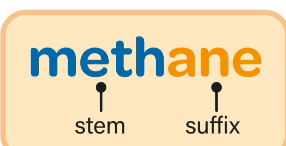
Chemistry of organic compounds

- Organic compounds typically contain carbon hydrogen bonds, while inorganic compounds do not.
- Hydrocarbons are a type of organic compound that can be separated from crude oil in a fractionating column to make a variety of products.

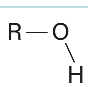
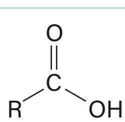


Fractionating column

- Names of organic compounds typically have a stem and a suffix.



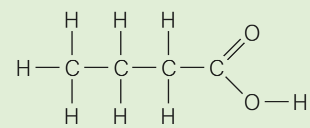
Number of carbon atoms in longest chain	Stem in IUPAC name
1	meth-
2	eth-
3	prop-
4	but-
5	pent-
6	hex-
7	hept-
8	oct-

Class	Functional group	Suffix in IUPAC name
Alkane	–C–C–	-ane
Alkene	–C=C–	-ene
Alkyne	—C≡C—	-yne
Alcohol		-anol
Carboxylic acid		-anoic acid

- Table 3.15 (page 119) shows the names of the first eight members of common homologous series.
- Organic compounds can be represented in different ways, e.g. butanoic acid

$C_4H_8O_2$

Molecular formula



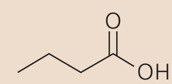
Structural formula

$CH_3CH_2CH_2COOH$

or

$CH_3(CH_2)_2COOH$

Condensed structural formula



Skeletal formula

- Hydrocarbons and other organic compounds can combust with oxygen to form carbon dioxide and water.

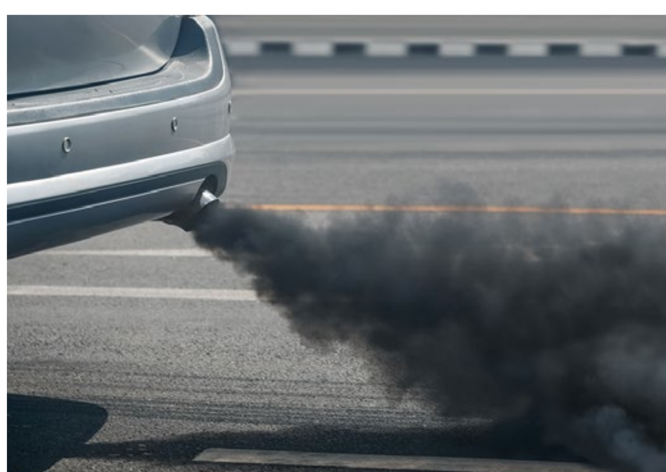
Hydrocarbon + oxygen → carbon dioxide + water + energy

- If there is limited oxygen, incomplete combustion will occur:

Hydrocarbon + limited oxygen → carbon monoxide + water + energy

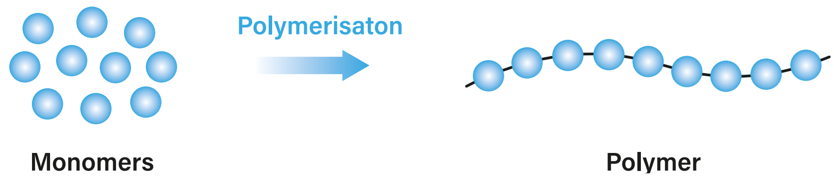
or

Hydrocarbon + limited oxygen → carbon + water + energy

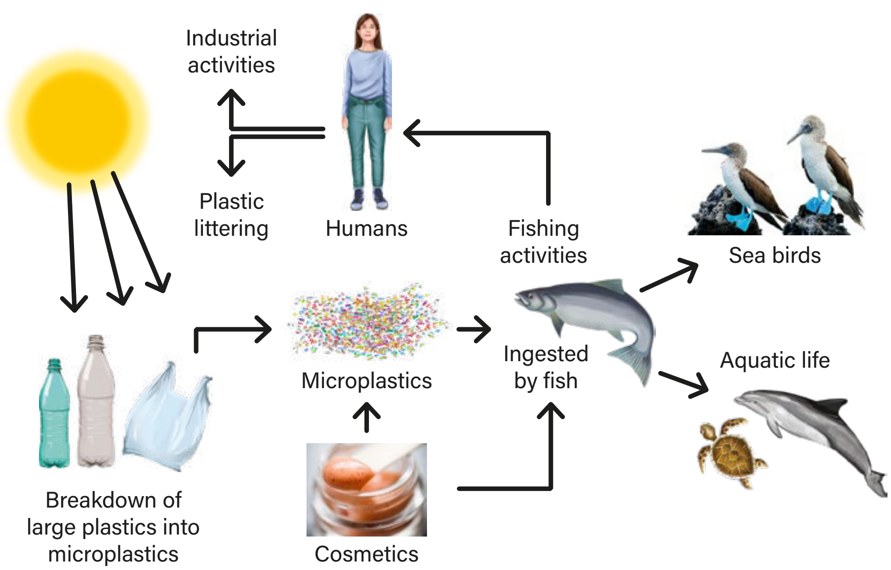


Polymers

- Crude oil is a raw organic material used to make polymers



- Polymers break down and accumulate in the environment as microplastics, which are harmful.



Property	Details and examples
Strength	HDPE is particularly strong and is used for plastic crates and piping.
Durability	Polyvinyl chloride (PVC) is used in piping because it can withstand harsh conditions over long periods of time.
Flexibility	LDPE can be rolled into sheets and used as food wrap.
Low reactivity	Addition polymers only contain single bonds, so they are generally inert (unreactive). Polyethylene containers can store corrosive substances such as acids.
Low thermal conductivity	Polypropylene is used in carpet and clothing fibres because it provides thermal insulation.
Low electrical conductivity	PVC piping is used as a covering for electrical wires because it does not conduct electricity.

Materials in context

- Plastics are useful but are not environmentally friendly.
- Bioplastics and other alternatives may be more environmentally friendly, but new technologies are continuously being tested and improved, such as those used as alternatives to plastic drinking straws.

Material	Intended use	Possible implications and impacts
Paper	Single use	▪ Break down while being used ▪ More than one used per drink ▪ Require trees as a resource
Metal	Reusable	▪ Very cold on the lips, especially for frozen drinks ▪ Treated like a single-use straw, wasting metal resources
Silicon	Reusable	▪ Large circumference, so may not please the consumer ▪ Treated like a single-use straw, wasting silicon resources and increasing landfill waste
PLA bioplastic	Single use	▪ Plants used for bioplastic rather than as food ▪ Limited shelf-life

Masterclass

Steps in progression

		1	2
Content	**Materials**	Classify the materials used in the *Deepsea Challenger*, Morph folding wheel and Fliteboard.	Describe the bonding model for titanium, a material used in the *Deepsea Challenger*.
Processes	**Planning investigations**	Describe how risks could have been minimised when prototypes of the Fliteboard were trialled.	Identify the variables (independent, dependent and controlled) that were most likely involved when the strengths of different polymer composites were tested for the Morph folding wheel.
Processes	**Problem-solving**	Propose a solution to not being able to surf when the waves are too small.	Explain how the materials used to construct the *Deepsea Challenger* are related to effects such as safety.
Processes	**Communicating**	Propose an appropriate way to communicate information about the Morph folding wheel to potential investors.	Prepare a digital presentation to promote the Fliteboard to university students.

Impactful materials

Selecting the right materials for engineering projects is critical, as the materials used directly impact the performance, safety and efficiency of the product or outcome. The *Deepsea Challenger*, for instance, is a submersible vessel designed to explore the deepest parts of the ocean. Engineers chose materials such as reinforced composite polymers and titanium for their strength and resistance to extreme pressure, which would allow the vessel to withstand the intense conditions of the Mariana Trench. Phenolic resin, a type of thermosetting polymer, serves as the 'hero' material, maximising the safety of the *Deepsea Challenger* and its pilot.

Morph folding wheels are an innovative contraption that can easily fold flat for transport versatility, without compromising the integrity of the wheel when in use. The designer of the wheel selected to use state-of-the-art glass-filled nylon polymer as the main material, to ensure a strong, durable frame while maintaining the wheel's flexibility and light weight – properties that make it ideal for wheelchairs.

Another example of an engineering wonder that relies on advanced materials to fulfil a particular purpose is the Fliteboard, an electric surfboard. Carbon-fibre and marine-grade aluminium make it possible for a small motor to power a fibreglass board while submerged in varying concentrations of salt water. These materials also ensure that the board is light in weight, yet strong enough to handle waves while providing excellent performance.

Each of these examples highlights how carefully chosen materials can enhance functionality and safety, showcasing the importance of material selection in engineering and product design. Understanding the chemistry and properties of different materials is essential for creating effective, innovative solutions in any field.

Demonstrate your understanding

3	4	5	
Explain why phenolic resin is a good choice of material. In your explanation, make reference to polymer bonding.	Discuss the environmental impacts of using polymers as a primary material in these products.	Select one of the materials highlighted in this Masterclass and evaluate how it is sourced and modified for its use.	
Propose an aim to align with the previous question and your response, in relation to testing possible materials for the Morph folding wheel.	Prepare steps for an investigation that is ethical, reliable and valid and meets the aim you proposed in step 3.	Describe the type of data that would be generated in your investigation and evaluate its appropriateness in addressing its aim.	Science how-to p. 405
Summarise the links between the criteria for developing a folding wheel to be used in a wheelchair and the materials selected.	Assess the significance of there being dozens of prototypes of a product before the design is finalised.	Evaluate the following statement: 'Carbon fibre is the best material because it is five times stronger than steel.'	Science how-to p. 425
Construct an infographic poster that outlines the significance of the materials used to construct the *Deepsea Challenger*. (Research is required.)	Present your infographics poster to your classmates, using the appropriate scientific conventions.	Evaluate the success of the maiden voyage of the *Deepsea Challenger* in March 2012, with reference to its design materials.	Science how-to p. 429

Figure 3.74: Engineers explored numerous prototypes, using a variety of materials, in developing the Fliteboard. The board is designed to tolerate submersion in salt water, as well as heat generated from the motor.

Figure 3.73: Canadian film director James Cameron carefully considered the purpose and impact of the materials selected to construct the *Deepsea Challenger*, an ocean submersible that was designed to reach the deepest-known part of the ocean.

Figure 3.75: The Morph folding wheel incorporates glass-filled polymer nylon, which is strong enough to hold the weight of the user while still allowing some flexibility.

Focus area 4

4.0 Environmental sustainability

Figure 4.1: Plastic pollution affects the livelihoods of marine organisms like this sea turtle.

The Sun's energy keeps our planet warm, allows plants to photosynthesise, and helps the atmosphere and oceans circulate. This, in turn, influences climate and weather. The landscape, along with sunlight and rainfall, determines what plants grow, which influences other organisms in the ecosystem. Human activity affects Earth, which means we need to do what we can to preserve our natural environments for future generations.

Learning Ladder

The Learning Ladder contains the scientific content and processes you will learn in this focus area. Each area has five levels of progression. To move to higher levels, you need to practise activities at the earlier levels. This will help you develop the ability to complete tasks that are more complex.

Steps in progression	Content: Environmental sustainability	Working scientifically processes: Analysing data and information	Working scientifically processes: Problem-solving
5	I can analyse how human activity has impacted the natural world.	I can evaluate conclusions based on the quality of data.	I can evaluate scientific claims based on evidence.
4	I can discuss a range of factors that can impact the natural world.	I can assess data and information for accuracy, reliability and validity.	I can assess problem-solving strategies used to solve an identified problem.
3	I can explain the impacts of natural phenomena and human-influenced processes on the environment.	I can draw conclusions based on patterns in data and information.	I can use given criteria to find solutions to scientific problems.
2	I can describe the effects of natural and man-made products on the natural world.	I can explain relationships between datasets and information.	I can explain scientific problems and phenomena using cause-and-effect relationships.
1	I can make observations about the natural world and things that impact it.	I can describe trends from collected data and information.	I can propose solutions to familiar scientific problems.

Figure 4.2: Environmental sustainability means supporting the health and wellbeing of all living things on Earth, now and in the future.

4.1 ▸ Principles and goals of sustainability: Western perspectives

Learning intention

At the end of this lesson, I will be able to identify and describe some of the principles and goals of sustainability.

Key terms

biodiversity: the variety of organisms in an ecosystem

ecosystem service: a benefit to humans provided by an ecosystem

sustainable: able to be maintained at a certain rate or level

Investigation 4.1

The sustainability game, page 519

Content group: Sustainability

Figure 4.3: The United Nations Sustainable Development Goals are interrelated – actions taken in one area will affect the others.

The principles and goals of sustainability aim to promote the responsible and ethical use of Earth's resources, protect the environment, and ensure a high quality of life for present and future generations.

Improving the environment requires a united approach

In 2015, the United Nations adopted 17 Sustainable Development Goals (SDGs) (Figure 4.3). The SDGs encourage governments, businesses and individuals to work together to improve the environment and the quality of human life by 2030.

We need to use resources carefully

Resources can be described as non-renewable (finite) or renewable (infinite). We need to use resources in a way that is beneficial for all humans, now and in the future.

Sustainable resource use can include:

- careful monitoring of natural resources such as fish populations and forests to prevent overharvesting
- the recycling of materials
- using alternative resources to prevent damage to the environment
- creating circular economies to reduce waste
- engaging with Indigenous knowledges and peoples to better care for Country.

We need to conserve ecosystems

We depend on the natural environment to survive. Our food is sourced from plants and animals, aquatic ecosystems provide clean drinking water, and photosynthesis creates oxygen. Bees pollinate our crops, coral reefs and mangroves prevent erosion of coastal areas, and humans obtain a sense of wellbeing from spending time in nature. These benefits to humans are known as ecosystem services and can be divided into provisioning (e.g. drinking water), regulating (e.g. soil fertility) and cultural services (e.g. recreation).

Human activity can disrupt the environment and natural ecosystems. Ecosystems can be destroyed by land clearing or damaged by pollution. Human activity can also support ecosystems through conservation efforts that preserve and restore habitats to protect the variety of species in the ecosystem – its **biodiversity**. It is important to conserve the natural environment so that we can continue to obtain these important **ecosystem services** for ourselves and future generations.

We need to preserve biodiversity

A biodiverse ecosystem contains many species. In an ecosystem, all living things are connected to each other, and the loss of one can result in the loss of them all. The more biodiverse an ecosystem is, the more stable it is and the more resistant it is to change. It is important to conserve biodiversity because different species provide us with different ecosystem services: bacteria and fungi act as decomposers to return nutrients to the soil, insects pollinate food crops, and many species of fish are important food sources. We also source many medicines from nature, antibiotics can be synthesised from chemicals produced by fungi, and painkillers can be derived from plants. If we lose species, we also lose these products.

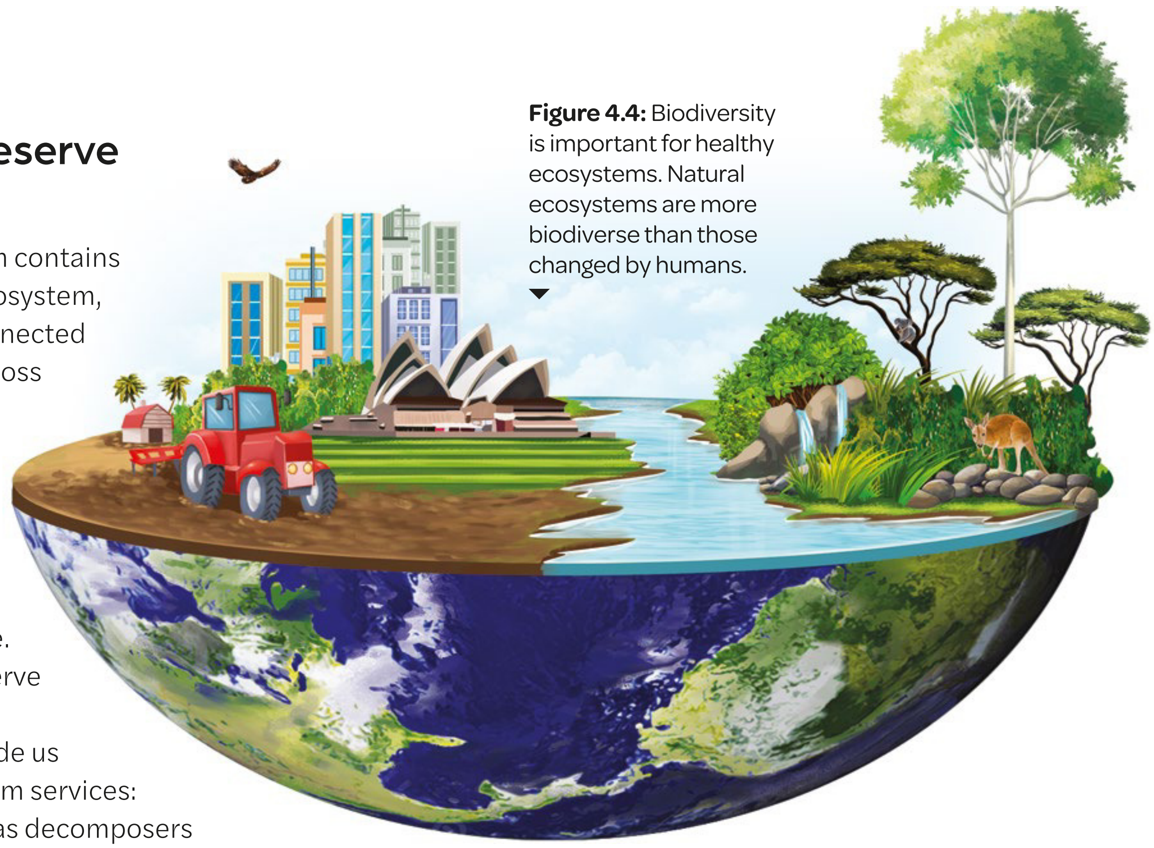


Figure 4.4: Biodiversity is important for healthy ecosystems. Natural ecosystems are more biodiverse than those changed by humans.

Unfortunately, biodiversity is declining. Habitat destruction, pollution, overharvesting and the introduction of invasive species are causing populations of many species to decline and increasing the risk of their extinction.

Learning Ladder

Environmental sustainability

1. Identify three important resources that are obtained from ecosystems.
2. Describe the effects of human activity such as pollution on natural ecosystems.
3. Explain the impacts of overharvesting on a population of fish.
4. Discuss the importance of the United Nations Sustainable Development Goals.
5. Analyse how human activity has affected biodiversity.

Problem-solving

see page 425

Waterways provide an important ecosystem service because they supply us with clean drinking water. Plastic pollution can contribute to the degradation of waterways.

1. Brainstorm some solutions to prevent plastic pollution from urban areas ending up in waterways.
2. Select one of your solutions and explain how it would work.
3. Conduct some research to find out about at least three strategies to prevent plastic pollution in waterways. Rank them in order of most effective to least effective.
4. Assess the strategies from Question 3 to identify the one most suitable for use in your local area.
5. Evaluate the importance of keeping waterways pollution free.

In context

Research one of the United Nations Sustainable Development Goals to find out what the goal aims to do and what progress has been made towards meeting it.

Success criteria

- I can identify and describe why conserving and preserving ecosystems is important for sustainability.
- I can identify and describe why using our resources carefully is important for sustainability.

4.2 ▸ Sustainability and caring for Country: Aboriginal and Torres Strait Islander perspectives

Learning intention

At the end of this lesson, I will be able to understand the importance of caring for Country and how it links to sustainability.

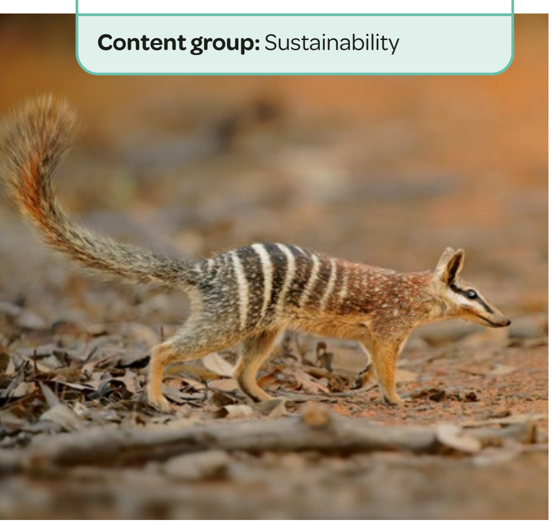
Key terms

Country: a complex concept that can include lands, waterways, coastlines, the sky and stars; also the complex lore, law, place, custom, tradition, spirit, culture, language, family and identity that are part of First Nations' cultures and knowledges

dominion: to have power or control over another thing

megafauna: the large mammals and marsupials that roamed across the continent of Australia and became extinct during the latter part of the Pleistocene period

Content group: Sustainability



▲
Figure 4.5: The numbat is one of many unique species that only live in Australia. It is one of the most endangered animals on the planet, with fewer than 1000 remaining in the wild today. To care for Country is to care for the numbat and all other endangered and threatened species. We have a responsibility to care for Country; otherwise, no numbats will survive for future generations.

Sustainability has always been at the heart of First Nations Peoples' caring for Country. By applying principles focused on ecology, food webs and the scientific method, Aboriginal and Torres Strait Islander Peoples have been able to thrive through extreme climate events like the last Ice Age (about 16 000–25 000 years ago), the mass extinction of Australian **megafauna** about 11 000 years ago, and a continent-wide mega-drought about 800 years ago.

Caring for Country is a priority

For Aboriginal and Torres Strait Islander cultures, **Country** does not mean a contemporary nation-state like Australia; rather, it includes all observable objects and phenomena in the human and the more-than-human realms. This means that the concept of Country often includes more than just land. Country is sacred and something that has rights and should be respected and cared for at every opportunity. For many, Country is not a commodity to be exploited, but is more like part of an extended family or even an extension of self.

As such, rather than owning land and having **dominion** over it in the Western sense, Country is something to be in a relationship with, and needs to be cared for as we would care for friends, family and our communities. In turn, Country cares for people in the same way.

Caring for Country means caring for people

The reasons for caring for Country do not necessarily explain *how* it should be cared for. First Nations Peoples' understandings of environmental science, ecology, food webs, climate, weather, geology, agriculture, aquaculture and many other scientific disciplines have informed them about how to care for Country. This means that, for generations of young First Nations people, the concept of sustainability was not taught in the same ways that it is today. *Caring for Country* was taught instead, the outcome of which was sustainability.

In addition, by considering people as belonging to Country and Country as belonging to people, it meant everyone had access to food, clean water, housing, education, health care and medicine, justice and respect. This is similar to the United Nations Sustainable Development Goals. Caring for Country has involved caring for people because when people are cared for, we are all better able to care for Country together.

Figure 4.6: A First Nations ranger and a non-Indigenous ranger work together to catch, check, tag and release crocodiles near Maningrida Kakadu in the Northern Territory. Working together is necessary to best care for Country.

An example of caring for Country is knowing when and where to light fires to clear undergrowth and reduce fuel load. These decisions would also be determined by mostly predictable seasonal variations of wind speed and direction. In some places, complex stories related to the reproductive cycles of plants and animals helped to inform when to conduct specific caring for Country practices. There were also knowledges that related to when and how to harvest specific plants to ensure that food could be cultivated without killing the plant. These practices ensured that there would be enough for everyone in the present and the future.

We need to understand Country to let it sustain us

Being connected to Country requires us to re-think how we interact with our environment and each other. Being connected to Country has allowed First Nations communities to be the oldest continuous cultures in the world, and has maintained environments that have supported populations through some of the most challenging climate conditions in history. We must recognise that what we take from Country will be taken from us or the next generation, but what we give to Country is given back to us and future generations. We have a responsibility to care for the future just as much as we care for the present.

Learning Ladder

Environmental sustainability

1. Identify the scientific disciplines First Nations' cultures have used to help care for Country.
2. Describe how First Nations Peoples have been able to thrive in challenging climates.
3. Explain how caring for people helps to care for Country.
4. Discuss how caring for Country supports being sustainable.
5. Analyse how First Nations cultures conceptualise their relationship with Country. How is this similar to or different from how Western cultures consider Country? How does this affect environmental sustainability?

Problem-solving

see page 425

First Nations Peoples' knowledge about how to care for Country is a great source of information about how to support biodiversity. This was severely disrupted with the colonisation of Australia.

1. Brainstorm some solutions that would include First Nations stakeholders and knowledge to support the ongoing biodiversity of Australia.
2. Select one of the solutions you identified and explain how it would work.
3. Identify where First Nations Peoples' knowledge is being applied to help care for Country. Describe the impact this strategy has had on Country.
4. Assess how the above knowledge would work if applied in your local area.
5. Evaluate the importance of working with Aboriginal and Torres Strait Islander Peoples to care for Country.

In context

Select one way of caring for Country and consider how it would in turn help to care for people.

Success criteria

- I can identify and describe how sustainability is an outcome of caring for Country.
- I can identify and describe why caring for Country is important for sustainability.

4.3 ▸ Climate and weather

Learning intention

At the end of this lesson, I will be able to distinguish between weather and climate.

Key terms

climate: trends in weather over a period of at least 30 years

climate zone: a region with a specific climate

meteorologist: a scientist who studies the atmosphere and its effects on Earth, including weather patterns

ocean circulation: the movement of water in the oceans due to major currents

weather: what is happening in the atmosphere at a specific place and time

Investigation 4.3

Observing the weather, page 520

Content group: Climate science

Figure 4.7: Weather describes what is happening in the atmosphere at a specific place and time.

The difference between climate and weather is a matter of time. Studying weather and climate can prepare us for extreme weather events and allow us to observe how climate trends are changing.

Weather happens over short periods

Weather describes what is happening in the atmosphere at a specific place and time – it can be minutes, hours, days or weeks. The weather is always changing because it depends on factors such as temperature, air pressure, wind, humidity and cloud formation. It can also be influenced by landforms and **ocean circulation**.

Meteorologists study the weather and use complex computer models to make predictions. Short-term forecasts are reasonably accurate, but long-term forecasting is more challenging.

Extreme weather events include cyclones, storms, floods and heatwaves. Being able to predict where and when they will happen allows communities to be prepared to respond.

Climate happens over longer periods

Climate describes the average weather patterns at a specific location or region over a period of at least 30 years. The climate for a region can be described using mean temperature and rainfall data at different times of the year, but it also includes data such as the frequency of extreme weather events. For example, Sydney has higher temperatures during summer and lower temperatures during winter, higher rainfall between February and June, and extreme thunderstorms between October and March. Northern parts of Australia have higher rainfall over summer (the wet season) than in winter (the dry season). Tropical cyclones are more common in these regions between November and April.

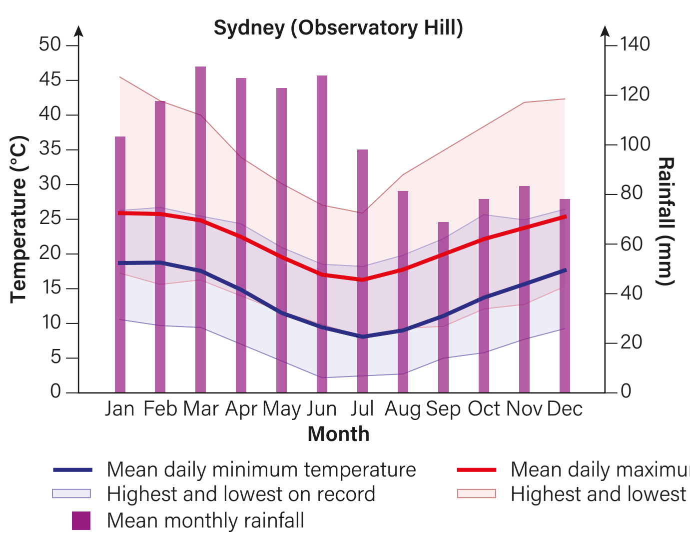


Figure 4.8: This graph shows climate data for Sydney using mean daily temperatures and mean monthly rainfall for data taken at Observatory Hill.

There are trends in climate across the world

Climate zones are regions with a specific climate. The Köppen climate classification system is one of the most widely used and is based on temperature and rainfall. In this system, there are five major climatic zones, as shown in Table 4.1 and Figure 4.9.

Table 4.1: Climate zones according to the Köppen classification system

Zone	Description
Tropical	Located at the equator High temperatures and high rainfall
Dry	Located north and south of the tropics Much less rainfall than in the tropics Includes deserts
Temperate and continental	Lower temperatures and high rainfall Coastal regions influenced by ocean currents Continental climates highly variable
Polar	Low temperatures, permanent ice caps

The global climate is changing

Long-term data shows that Earth's climate is changing, driven by an increase in atmospheric temperature. This influences rainfall, ocean temperatures and ocean circulation.

Australia's average temperature has risen by 1 °C since 1910 (Figure 4.10). In this time, we have observed more extreme heatwave events, prolonged droughts and longer bushfire seasons. Cyclones are increasing in strength and are forming further away from the equator and outside of the expected season.

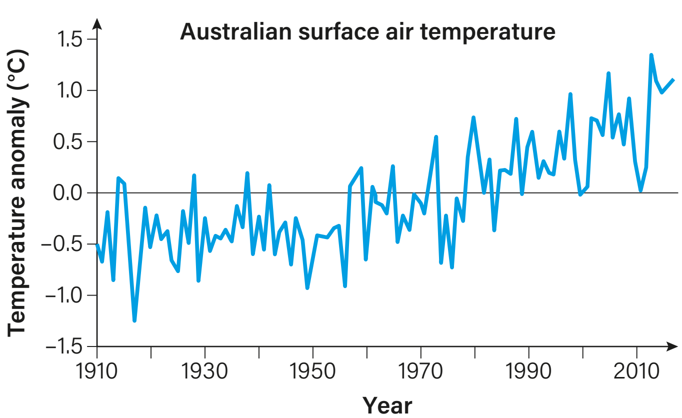


Figure 4.10: Australia's average temperature has increased by 1 °C on average since 1910. This data shows how far the average temperature has varied from the 1961–90 average.

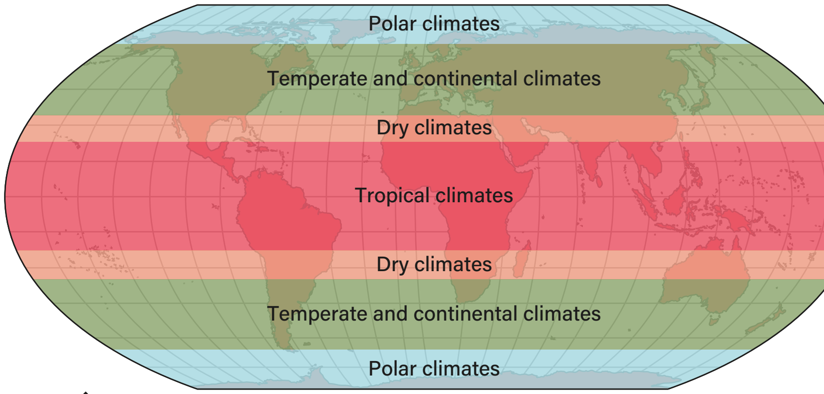


Figure 4.9: A simplified map of global climatic zones

Learning Ladder

Environmental sustainability

1. Identify an observation you could make to describe the weather today.
2. Describe the characteristics of the climate zone that New South Wales is part of.
3. Explain the difference between weather and climate.
4. Discuss the changes in climate you would observe if you were to travel from the equator to the poles.
5. Analyse how changing patterns in extreme weather events could affect communities.

Analysing data and information see page 420

Use the data in Figures 4.8 and 4.10 to answer these questions.

1. Describe the trends in the mean monthly rainfall data from January to December.
2. Explain the relationship between mean daily maximum and minimum temperature and time of the year.
3. Predict the trend that may be observed in Australia's temperature data between 2030 and 2050.
4. Discuss the data that would be needed to be collected and analysed to support the statement: 'Australia's average temperature is rising.'
5. Use the data to evaluate the statement: 'Temperatures in Sydney are rising.'

In context

The Australian continent experiences three major climatic zones. Propose how this influences the weather from the north to the south of the continent.

Success criteria

- I can distinguish between weather and climate.
- I can identify global climate trends.

4·4 ▸ The atmosphere and the greenhouse effect

Learning intention

At the end of this lesson, I will be able to explain the impact of the atmosphere and the greenhouse effect.

Key terms

atmosphere: the layer of gas that surrounds Earth and is 600 km thick

greenhouse effect: the trapping of the Sun's heat by Earth's atmosphere

greenhouse gas: a gas that traps the Sun's heat energy in Earth's atmosphere

Investigation 4.4

The greenhouse effect, page 521

Content group: Climate science

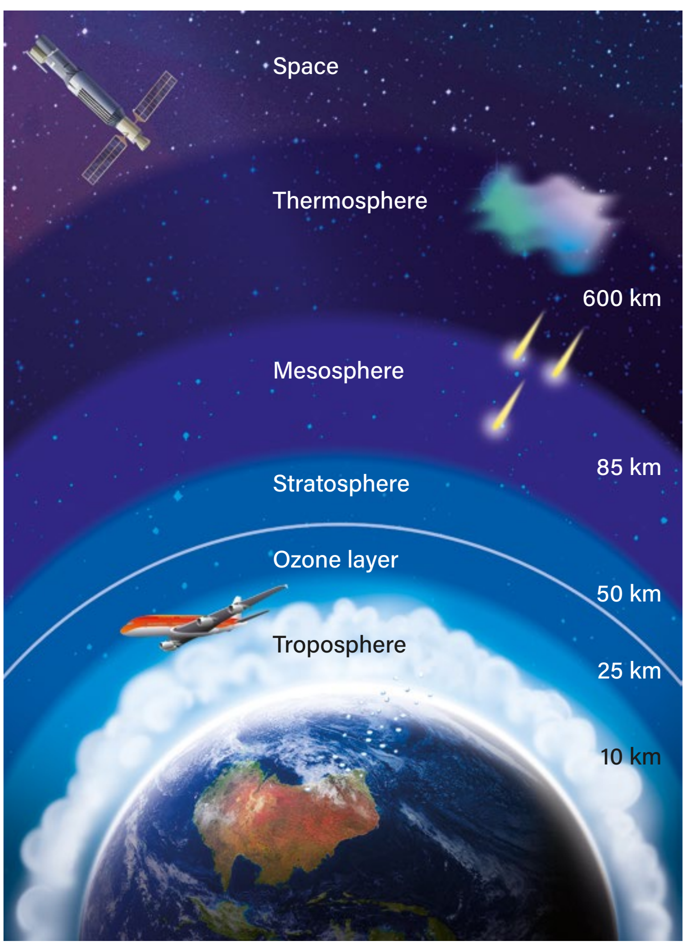
A greenhouse is a glass structure that gardeners use to trap the Sun's energy and keep plants warm. The glass allows the energy through but prevents some of it from escaping. Earth's atmosphere acts in a similar way. Without the atmosphere, all the Sun's energy would escape, leaving Earth to be a frozen planet.

The atmosphere is a layer of gas

The **atmosphere** is the 600 km thick layer of gas that surrounds Earth. The atmosphere protects life on Earth from harmful radiation by either absorbing it or reflecting it back into space.

The atmosphere is made up of four major layers (Figure 4.11):

- troposphere – the bottom layer: where we live, aeroplanes fly and weather takes place
- stratosphere – contains the ozone layer
- mesosphere – where meteorites burn up
- thermosphere – where auroras happen.



The atmosphere contains oxygen, which we breathe, and carbon dioxide, which plants use for photosynthesis. Oxygen makes up about 21 per cent of the gases in the atmosphere. Other gases are nitrogen (78 per cent), argon (0.93 per cent) and carbon dioxide (0.04 per cent). The atmosphere also contains minute quantities of neon, helium, methane, water vapour, krypton, hydrogen, xenon and ozone.

The greenhouse effect keeps Earth's surface warm

When the Sun's solar radiation hits the surface of Earth, some of it is reflected back into space and some is absorbed by Earth's surface, warming it. The warm surface emits energy as infrared radiation, which will leave Earth and travel back out to space unless something prevents it from doing so.

A **greenhouse gas** is a gas that stops this infrared energy from going straight back out into space. Molecules of greenhouse gases absorb and then re-emit this energy, warming the lower atmosphere

Figure 4.11: Earth's atmosphere consists of four major layers: the troposphere, stratosphere, mesosphere and thermosphere.

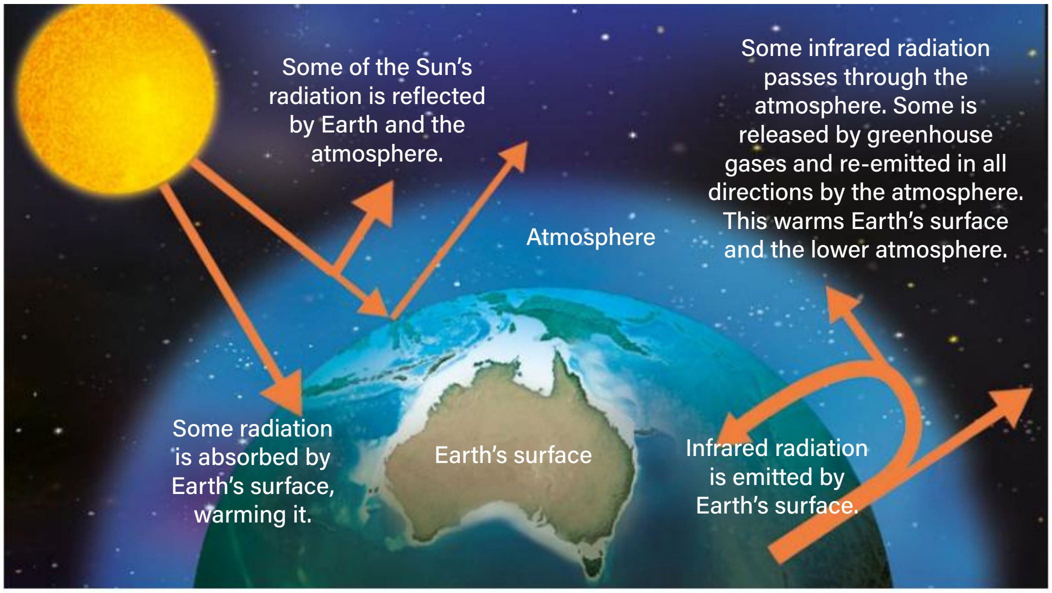


Figure 4.12: The greenhouse effect is important for maintaining the temperature on the surface of Earth.

and the surface of Earth. This is known as the **greenhouse effect**, and without it, the surface of Earth would be −18 °C.

Greenhouse gases trap heat

The major greenhouse gases in the atmosphere are water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). These gases are only present in the atmosphere in very small quantities (Table 4.2), but it is enough to trap energy to keep Earth's surface warm – an average of about 13.6 °C in pre-industrial times. The molecules of some greenhouse gases, such as nitrous oxide, can stay in the atmosphere for a long time – more than 100 years. Others, such as water vapour, stay in the atmosphere for only a short time – up to a few days.

Table 4.2: Atmospheric concentration of common greenhouse gases

Greenhouse gas	Pre-industrial concentration (parts per million, ppm)
Water vapour, H_2O	1–3
Carbon dioxide, CO_2	280
Methane, CH_4	0.7
Nitrous oxide, NO_2	0.27

Learning Ladder

Environmental sustainability

1. Identify the most common gas in Earth's atmosphere.
2. Describe what can happen to solar radiation when it reaches Earth.
3. Explain how greenhouse gases in the atmosphere keep Earth warm.
4. Discuss the importance of greenhouse gases in the atmosphere for life on Earth.
5. Analyse the potential impact long-lived greenhouse gases, such as nitrous oxide, would have on the greenhouse effect.

Analysing data and information *see page 420*

1. Describe what would happen to Earth's surface temperature over a 24-hour period if there were no atmosphere.
2. Explain the relationship between concentration of greenhouse gases in the atmosphere and the temperature of a planet.
3. The atmosphere of Venus is about 96 per cent carbon dioxide. Predict what effect this has on surface temperatures on the planet.

In context

Suggest why a comparison with a gardener's greenhouse is used to explain the greenhouse effect.

Success criteria

- I can describe the atmosphere.
- I can identify major greenhouse gases.
- I can explain the effect of the natural greenhouse effect.

4.5 ▶ The enhanced greenhouse effect

Learning intention

At the end of this lesson, I will be able to evaluate scientific evidence for the effect that human activity has on the greenhouse effect.

Key terms

enhanced greenhouse effect: an increase in the greenhouse effect due to human greenhouse gas emissions

Industrial Revolution: a period in the late 1700s when manufacturing transformed to large-scale factories that were powered by the burning of fossil fuels

Content group: Climate science

Humans have added more greenhouse gases into the atmosphere, which has artificially enhanced the greenhouse effect, raising the average temperature of Earth by about 1 °C.

Humans have increased the greenhouse effect

Since the **Industrial Revolution**, human activity, such as the burning of fossil fuels and factory emissions, has increased the levels of greenhouse gases in the atmosphere. Because there are more gas particles, more infrared radiation stays in Earth's atmosphere and less is radiated back into space. This is called the **enhanced greenhouse effect**.

Figure 4.13: A comparison of the natural greenhouse effect and the enhanced greenhouse effect

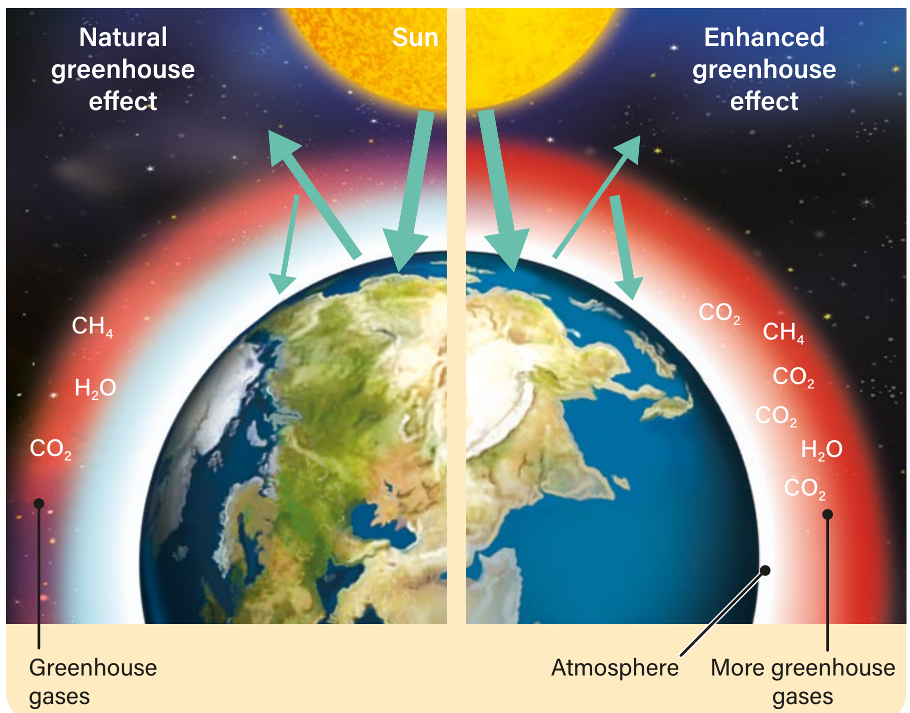
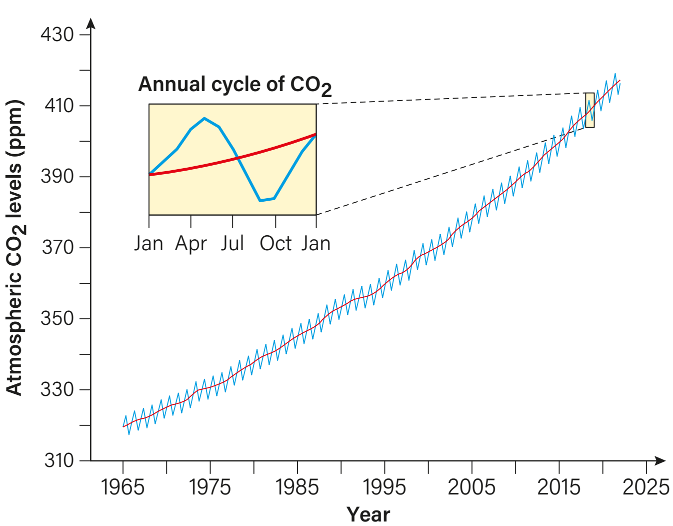


Figure 4.14: The Keeling curve shows atmospheric carbon dioxide concentration (in ppm) from 1956 to today.



Atmospheric CO_2 levels are increasing

Scientists can measure the amounts of greenhouse gases in the atmosphere and correlate this with average temperatures to demonstrate the relationship between the two. A global network of stations samples the atmosphere regularly, including Mauna Loa Observatory on the Big Island of Hawaii and the Kennaook/Cape Grim Baseline Air Pollution Station in north-west Tasmania. Measurements taken at Kennaook/Cape Grim show that carbon dioxide levels in the atmosphere are increasing. In 2024, the atmospheric concentration of carbon dioxide was about 425 ppm (parts per million).

The Keeling curve plots CO_2 levels in the atmosphere

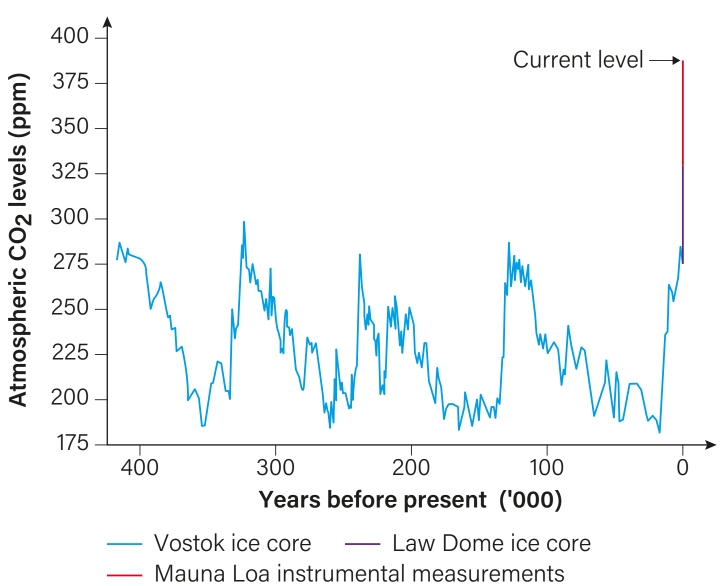
In 1958, US scientist Charles Keeling started monitoring carbon dioxide concentrations in the atmosphere at Mauna Loa, in Hawaii. His research showed that the concentration of carbon dioxide in the atmosphere was steadily increasing and changed throughout the year.

The annual cycle is because most of Earth's land mass and plant life are in the northern hemisphere. Over the northern spring and summer, plant growth and photosynthesis increase, which reduces carbon dioxide in the atmosphere. During autumn and winter, plant growth and photosynthesis decline and levels of carbon dioxide in the atmosphere increase. When plotted as a graph, this data is known as the Keeling curve (Figure 4.14).

Ice core data also shows CO_2 levels are increasing

Ice cores are cylinders of ice drilled from ice sheets. Scientists use ice cores that are up to 800 000 years old to find out more about Earth's past temperature and climate. Importantly, they can analyse air bubbles trapped in the ice to determine the concentration of gases in Earth's atmosphere over time.

Data from ice cores shows that the recent increase in carbon dioxide levels due to human activity is unprecedented (Figure 4.15).



▲ **Figure 4.15:** Combined data from the Vostok and Law Dome ice cores in Antarctica and from Mauna Loa show how the carbon dioxide concentration in the atmosphere has varied over the last 400 000 years.

Learning Ladder

Environmental sustainability

1. Identify the cause of the enhanced greenhouse effect.
2. Distinguish between the natural and enhanced greenhouse effects.
3. Explain a potential impact of increased concentrations of greenhouse gases in the atmosphere.
4. Discuss the importance of using ice core data to evaluate the impacts of human activity on carbon dioxide levels.
5. Analyse the data on atmospheric carbon dioxide levels to explain the impact on atmospheric temperature. Note: You may need to refer to the Australian temperature trends in Figure 4.10.

Analysing data and information

see page 420

1. Describe the trends in atmospheric carbon dioxide concentration shown in the Keeling curve (Figure 4.14).
2. Explain the reason for the annual fluctuation in atmospheric carbon dioxide levels in the Keeling curve.
3. Extrapolate the data in the Keeling curve to predict the amount of carbon dioxide in the atmosphere in 2030 and 2035.
4. Assess the validity and reliability of atmospheric carbon dioxide data gathered at Mauna Loa and Kennaook/Cape Grim to inform the levels across the globe.
5. Evaluate the statement: 'Carbon dioxide levels in the atmosphere have increased at unprecedented levels since 1950.'

In context

Create an animation or a poster to help you explain the difference between the natural and enhanced greenhouse effects to people in your local area.

Success criteria

- I can describe how human activity has enhanced the greenhouse effect.
- I can discuss some of the evidence for the enhanced greenhouse effect.

4·6 ▸ Reducing greenhouse gas emissions

Learning intention

At the end of this lesson, I will be able to identify the advantages and limitations of methods used to reduce greenhouse gas emissions.

Key terms

carbon sequestration: the process of capturing and storing atmospheric carbon dioxide

energy efficiency: how much usable energy is produced compared to how much energy has been supplied

greenhouse gas emission: the production of a greenhouse gas

net zero emissions: the greenhouse gas emissions that are produced are balanced out by those that are absorbed by other processes

Content group: Climate science

Many technologies and practices are being developed to achieve net zero carbon emissions over the next few decades.

The international community has agreed to reduce greenhouse gas emissions

The Intergovernmental Panel on Climate Change (IPCC) is a United Nations group that has stated that reducing emissions of carbon dioxide and other greenhouse gases will reduce the concentration of these gases in the atmosphere and thus reduce global temperature increases.

Governments have agreed to address these issues and reduce the **greenhouse gas emissions** of their countries. Major agreements include the Kyoto Protocol (1997) and the Paris Agreement (2015).

Australia plans to reduce its emissions to 43 per cent below its 2005 levels by 2030 and to reach **net zero emissions** by 2050.

We are changing how we power ourselves

Electricity to power homes, workplaces, factories and cities contributes the highest amount to Australia's greenhouse gas emissions. Phasing out coal and gas in favour of renewables such as solar and wind, accompanied by storage facilities such as batteries and pumped hydro, will reduce emissions. Switching the manufacturing industry to be fully electric, instead of relying on fossil fuels, will significantly reduce emissions.

We can reduce our personal greenhouse gas emissions by:

- switching from gas to electrical appliances
- switching to more **energy-efficient** appliances

Figure 4.16: Installing solar panels and switching to more energy-efficient appliances will reduce greenhouse gas emissions.

Figure 4.17: Generating electricity from renewable sources such as wind instead of fossil fuels will reduce greenhouse gas emissions.

- being mindful of energy use, such as switching appliances off at the wall when they are not in use
- installing solar panels and battery storage so that households can run off the energy they produce.

Changing transport will reduce emissions

After power generation and the manufacturing industry, transport is the third-largest source of greenhouse gas emissions in Australia. Switching the transport industry to use rail for freight and using electric vehicles will significantly reduce emissions.

We can reduce our personal transport greenhouse gases by:

- using public or active transport
- switching to hybrid or electric vehicles
- reducing our air travel.

Changing how we use land will reduce emissions

Although crops act as a carbon sink, the land management and agricultural sectors also contribute to greenhouse gas emissions in Australia. Clearing native forests removes an important carbon sink, and livestock produce high levels of methane. Changing agricultural practices to encourage more **carbon sequestration** in soils, reducing methane production by changing the food provided to livestock, and stopping the clearing of native forests can help to bring the carbon emissions produced by the land-management and agricultural sectors to net zero.

Challenges exist in reducing greenhouse gas emissions

Barriers to reducing greenhouse gas emissions are mostly economical. For some countries, fossil fuels are still the cheapest form of energy. Many countries, including Australia, rely heavily on the income from the mining and sale of fossil fuels. New technologies can be expensive and require rare earth metals, the processing of which can cause other environmental damage. Vehicle batteries cannot yet store enough power to last the long distances travelled by vehicles in Australia, so this is a barrier to the use of electric vehicles.

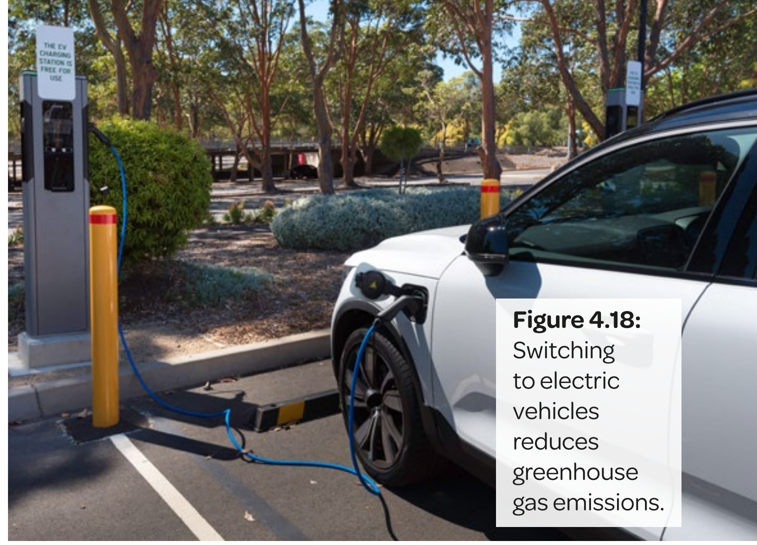


Figure 4.18: Switching to electric vehicles reduces greenhouse gas emissions.

Learning Ladder

Environmental sustainability

1. Identify five ways that your lifestyle results in greenhouse gas emissions.
2. Describe the effect that not controlling greenhouse gas emissions will have on Earth.
3. Explain one of the impacts on Earth of implementing strategies to reduce greenhouse gas emissions.
4. Discuss the importance of using renewable sources to generate electricity in order to reduce greenhouse gas emissions.
5. Analyse the impacts of banning vehicles powered by fossil fuels in Australia.

Problem-solving

see page 425

1. Propose how you could change your lifestyle to reduce your greenhouse gas emissions.
2. Explain how replacing gas appliances with electric ones can reduce greenhouse gas emissions.
3. Australia plans to reach net zero carbon emissions by 2050. Discuss the most important changes that need to be made to reach this goal.
4. Assess the effectiveness of the strategy to move all electricity generation to renewable sources such as wind and solar in reducing greenhouse gas emissions.
5. Evaluate how improving land-management strategies will affect Australia's overall greenhouse gas emissions.

In context

Discuss some strategies for limiting the amount of carbon emissions produced by a small dairy farm.

Success criteria

- I can identify some advantages and limitations of methods used to reduce greenhouse gas emissions.

4.7 ▸ Climate change

Learning intention

At the end of this lesson, I will be able to describe some of the impacts of increasing atmospheric temperatures on Earth.

Key terms

glacier: a slowly moving mass of ice formed by the accumulation of snow

precipitation: liquid or solid water that forms in the atmosphere and falls to Earth's surface

thermal expansion: the increase of volume of a substance due to an increase in temperature

water cycle: the cycle of processes by which water circulates between Earth's oceans, atmosphere, land and biosphere

Investigation 4.7A

Modelling thermal expansion , page 523

Investigation 4.7B

Melting ice and sea-level rise , page 525

Content group: Impacts of present-day climate change

Earth's climate is changing. Long-term data shows that Earth's average temperature has increased since 1880. This is influencing weather patterns, sea levels, ocean temperatures, and the presence of ice at the poles.

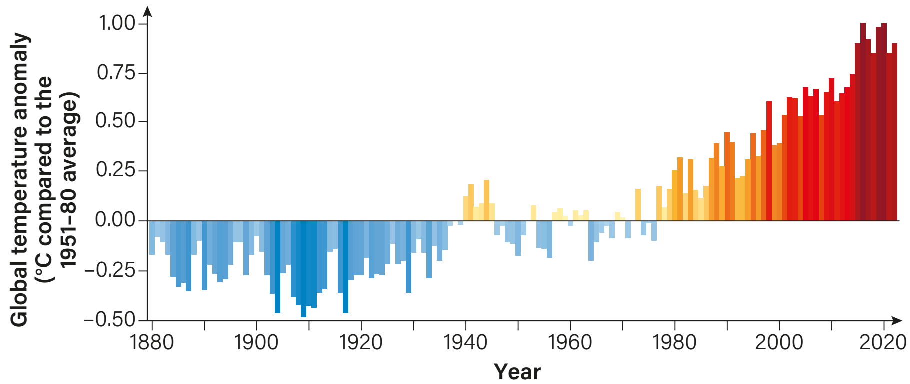
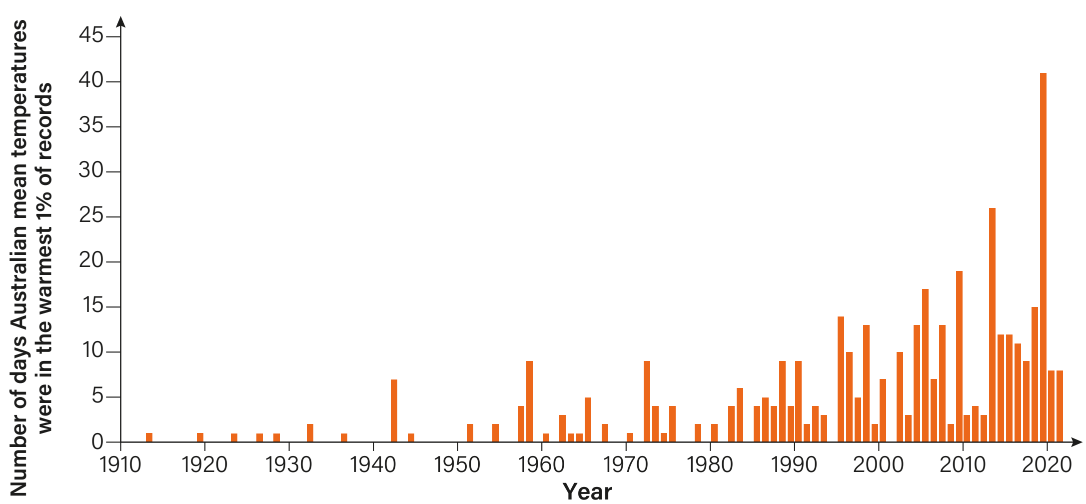


Figure 4.19: The world's average temperature has increased by more than 1 °C since 1880. This graph shows how far the average temperature has varied from the 1951–80 average.

Evaporation and precipitation will increase

Water moves around Earth in the **water cycle**. Increasing temperatures are causing some parts of the water cycle to speed up. As the oceans get warmer, more water evaporates, which means that more water moves into the atmosphere. This results in more cloud formation, more **precipitation** and larger storms. Climate modelling shows that rainfall patterns will also change, with a lot more precipitation over the oceans or along the coastlines of continents, and the interior of the continents becoming dryer. If there is more water in the atmosphere, rainfall events can become larger, resulting in flooding. Higher temperatures, and therefore evaporation in regions that receive low rainfall, will result in more extreme droughts.

Figure 4.20: ▸ The number of days when mean temperatures were in the top 1 per cent of records has increased in Australia since 1910.



Melting ice contributes to rising sea levels

The increase in global temperatures has led to a reduction of ice at the poles, as well as in **glaciers** on continents. When glaciers and other continental ice melts, the water runs off into the oceans, contributing to sea-level rise. Figure 4.21 shows how the Franz Josef glacier in New Zealand has changed since 2009.

When sea ice melts, it leaves dark-coloured sea water behind, which absorbs incoming solar energy instead of reflecting it, like ice does. This increases the sea temperature and melts the remaining sea ice faster. Satellite imagery has shown that there has been a 13 per cent reduction in the permanent summer sea ice in the Arctic each decade since the late 1970s (Figure 4.22). It is predicted that the Arctic Ocean will have ice-free summers by the 2050s.

Figure 4.21: The Franz Josef glacier, on the west of the South Island of New Zealand, retreated about 800 m between 2009 and 2020. It has retreated about 3 km since the late 1800s.

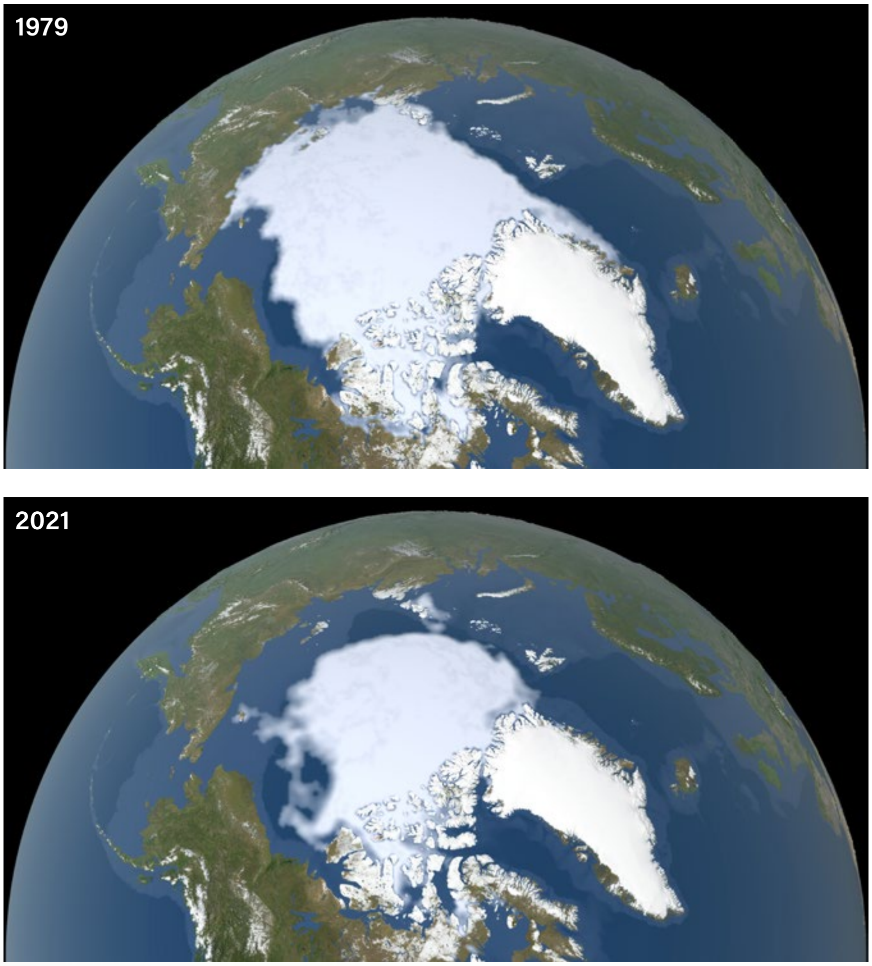


Figure 4.22: The extent of the permanent summer sea ice in the Arctic Ocean has decreased by 13 per cent every decade since 1979.

Heatwaves and bushfires will become more frequent

A heatwave is a period of three or more days of higher-than-normal temperatures for a particular region. Not only are temperatures expected to rise, but heatwave events are expected to become more frequent and of longer duration. This will cause challenges for communities, as they need to develop infrastructure to support people who are vulnerable to the extreme temperatures.

The high temperatures and dry conditions produced by climate change also increase the risk of bushfires. Bushfires move rapidly through dry vegetation. In Australia, high temperatures are causing the bushfire season to extend into spring and autumn and the number of extreme fire danger days to increase.

Figure 4.23: Iluka, New South Wales, November 2019. The 2019–20 bushfire season was the worst ever recorded in New South Wales and across Australia. It was brought about by severe drought combined with intense fire behaviour. Millions of hectares were burned, plus homes were destroyed and lives were lost.

Sea levels are rising

Sea levels have risen 0.10–0.20 m around the world in the last century. Some of this rise is attributed to melting glaciers, but at least half is caused by **thermal expansion**. The amount by which sea levels rise varies around the world because the strength of winds and ocean currents varies, and this affects how much heat can be stored in the deeper parts of the ocean.

As the water in the ocean absorbs more heat energy, this is transferred to the water molecules, which vibrate more rapidly and move further away from each other, increasing the volume of the water.

As sea levels rise, this will put pressure on coastal communities and threaten infrastructure such as roads and buildings.

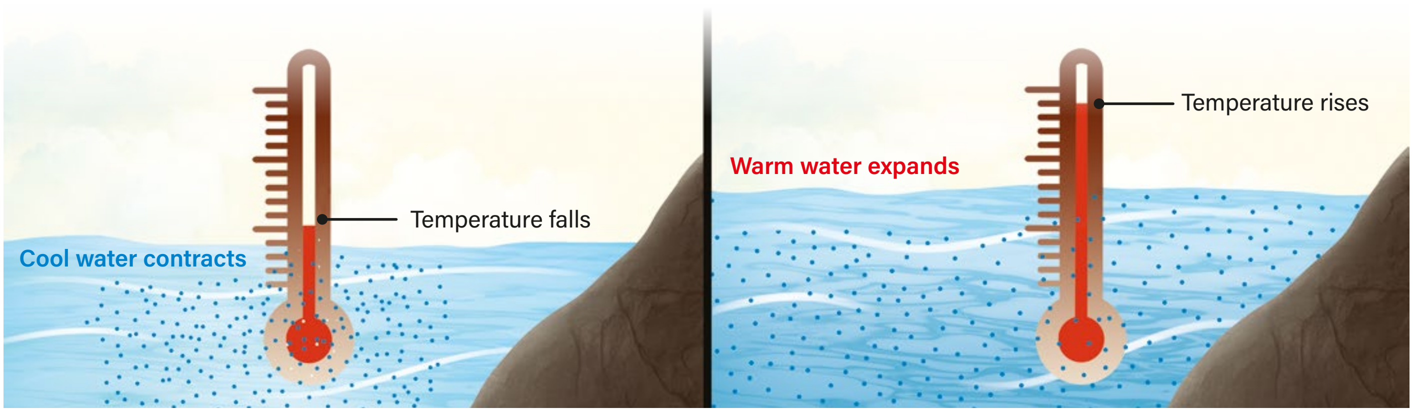


Figure 4.24: As the temperature of the water increases, the molecules push each other further apart and so the volume increases.

Learning Ladder

Environmental sustainability

1. Identify the following statements as true or false.
   - **a** Higher levels of carbon dioxide in the atmosphere are causing Earth to cool.
   - **b** Higher atmospheric temperatures will result in more evaporation and precipitation over the oceans.
   - **c** Warm water takes up more space than cool water.
2. Describe the effect that increasing atmospheric temperatures has had on ice in the Arctic Ocean.
3. Explain how higher atmospheric temperatures are causing sea-level rise.
4. Discuss the effect of climate change on the frequency and severity of bushfires.
5. Analyse how the burning of fossil fuels has affected the natural world.

Analysing data and information

see page 420

1. Describe the trends shown in:
   - **a** Figure 4.19.
   - **b** Figure 4.20.
2. Explain the relationship between increasing sea temperatures and rising sea levels.
3. Predict what will happen to the number of extreme temperature days in Australia if carbon dioxide levels in the atmosphere continue to rise.
4. Assess the usefulness of the data in Figures 4.19 and 4.20 for identifying a relationship between increasing temperatures and the number of extreme temperature days in Australia.
5. Use the data provided to evaluate the statement: 'The effects of climate change have increased since the 1980s.'

In context

Write some questions you could ask your parents and grandparents about how they have experienced climate change during their lifetimes.

Success criteria

- I can describe how increased atmospheric temperatures are affecting evaporation and precipitation.
- I can describe how increased atmospheric temperatures are increasing the risk of heatwaves and bushfires.
- I can describe how increased atmospheric temperatures are reducing the size of glaciers and permanent sea ice at the poles.

4.8 ▸ Effects of climate change

Learning intention

At the end of this lesson, I will be able to describe some of the consequences of climate change.

Key terms

alpine: areas of high elevation

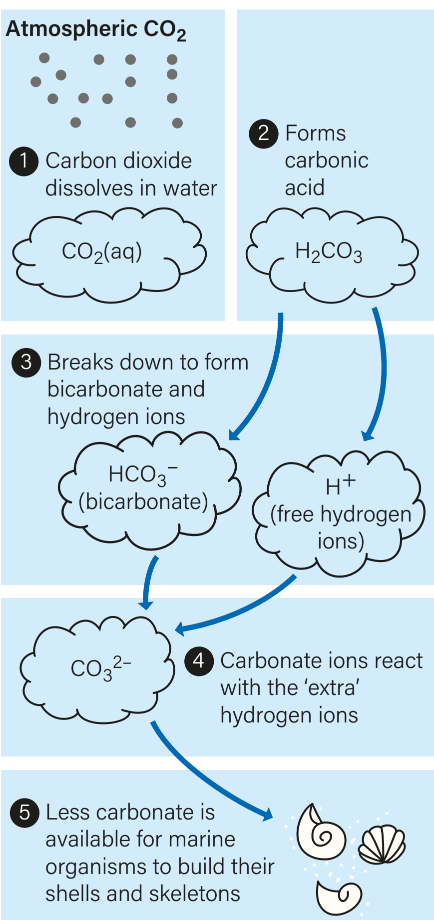
carbon cycle: the natural cycling of carbon through ecosystems

ocean acidification: a decrease in the pH of the oceans due to the absorption of more carbon dioxide

Investigation 4.8

Modelling ocean acidification, page 526

Content group: Impacts of present-day climate change



▲ **Figure 4.25:** Ocean acidification is caused by higher amounts of carbon dioxide being absorbed by oceans.

Climate change is affecting ecosystems worldwide as natural processes are disrupted. Increased levels of atmospheric carbon dioxide are causing ocean acidification, and high temperatures are leading to habitat loss.

Oceans are becoming more acidic

Oceans absorb carbon dioxide from the atmosphere as a natural part of the **carbon cycle**, but the amount they are absorbing is increasing as the amount of carbon dioxide in the atmosphere increases.

When carbon dioxide dissolves in water, it undergoes a chemical reaction to form carbonic acid (H_2CO_3). The carbonic acid then breaks down, releasing hydrogen ions (H^+) that react with free carbonate ions (CO_3^-) in the water to form bicarbonate. This decreases the pH of oceans, leading to **ocean acidification**.

The chemical reactions also mean that less calcium carbonate ($CaCO_3$) is available for zooplankton, coral and shellfish, which need it to build their shells and skeletons. As well, the carbonate in their shells reacts with hydrogen ions in the water, so these organisms cannot grow or they produce thinner shells that are more easily damaged. This will have flow-on effects in the ocean ecosystem, as important organisms in food webs start to disappear.

Climate change is causing habitat loss

Across the world, we are observing habitat loss due to climate change. The Arctic is warming almost twice as quickly as anywhere else in the world, affecting the level of sea-ice coverage. This is limiting the habitat available for polar bears.

Polar bears have evolved to rely on the sea ice as a platform for hunting seals. They do most of their hunting over winter and spring, storing energy for summer and autumn. In the southern areas of the polar bears' habitat, such as Hudson Bay in Canada, the sea ice now melts earlier in spring and forms later in autumn, reducing the time available to hunt. Previously, polar bears would have rested for the short period of time when there is no sea ice, but now their time on land is extended. For every week the ice breaks up earlier, the bears can be about 10 kg lighter and in poorer condition. This is leading them to scavenge for food on land and can even lead to starvation. Habitat loss due to climate change is the biggest threat to the survival of the polar bear.

Many Australian species are also experiencing habitat loss due to climate change. There are thought to be fewer than 2000 mountain pygmy possum left in the wild, living in small populations in the **alpine** regions of northern Victoria and southern New South Wales.

Figure 4.26: A female polar bear hunts a ringed seal to feed her cubs.

Their primary habitat is boulder fields – the rocks provide shelter from the extreme winter cold and the summer heat.

Mountain pygmy possums are one of the few Australian mammals that hibernate during winter when food is scarce. Snow in winter provides an insulating layer on top of the boulder fields, preventing the temperatures from dropping below freezing and keeping the mountain pygmy possums warm. If there is no snow cover, the unprotected mountain pygmy possums can freeze to death. Changing snowfall patterns and early snowmelt are contributing to population decline, as the mountain pygmy possums' habitat is reduced to smaller and smaller areas that receive the required snow cover over winter.

Figure 4.27: Mountain pygmy possums live in alpine boulder fields. They rely on winter snow cover to provide insulation for their habitat.

Learning Ladder

Environmental sustainability

1. Identify the main cause of climate change.
2. Describe the effect of excess carbon dioxide in oceans on the pH of the water.
3. Explain the relationship between summer sea ice and the health of polar bears.
4. Discuss the impacts of rising temperatures on habitat loss.
5. Analyse how increased carbon dioxide in the atmosphere is affecting ocean ecosystems.

Analysing data and information *see page 420*

1. Describe how the pH of the oceans has changed over the last 200 years.
2. Explain the relationship between atmospheric carbon dioxide concentration and sea temperatures.
3. Predict what may happen to coral reefs if carbon dioxide emissions are not reduced.
4. Explain how the reduction in Arctic sea ice and changes in snowfall patterns in the Australian alpine regions provide reliable evidence for global climate change.
5. Evaluate the relationship between increased atmospheric carbon dioxide levels and a decrease in the polar bear population.

In context

In many cases, organisms cannot keep up with the rapid changes to their habitats caused by climate change. One strategy being implemented by land managers in Australia is 'assisted colonisation', or the act of moving plants or animals to new places to help them survive as their existing habitat changes. Discuss the benefits of this type of strategy for maintaining biodiversity.

Success criteria

- I can describe how increased atmospheric carbon dioxide levels lead to ocean acidification.
- I can describe how climate change is causing habitat loss.

4.9 ▸ Using data to evaluate the impact of climate change

Learning intention

At the end of this lesson, I will be able to discuss how data can be used to evaluate the impact of climate change.

Key terms

coral atoll: a ring-shaped island formed by a coral reef

coral bleaching: a phenomenon where corals lose their colour due to the absence of symbiotic algae

groundwater: water that flows underground in spaces between rocks and within soils

Content group: Impacts of present-day climate change

Scientists collect data using technology such as satellites. The data can be used to create models that predict how a changing climate will affect communities in the future.

Reduced precipitation will result in shorter ski seasons

Warmer winters and reduced precipitation will result in less snowfall in the alpine regions of southern New South Wales, Victoria and Tasmania. This will affect the fragile alpine ecosystems that rely on the snow cover and the waterways that are fed by the spring snowmelt. It will also affect the ski season, an important contributor to the economies of these regions.

Scientific modelling has shown that the length of time when temperatures are low enough for snow to fall and stay on the ground is decreasing. A ski resort needs to be able to maintain about 30 cm of snow on the ground of the ski runs, but the depth of natural snowfall has been declining since the 1950s. To continue operating, ski resorts will need to rely more on expensive snowmaking activities to supplement natural snowfall. However, this process still requires low temperatures. If greenhouse gas emissions continue to increase at their current rate, the length of the ski season will halve by 2050 – from an average of 110 days to 55 days. Precipitation will reduce by 4–25 per cent over that time.

Snowfall will be restricted to higher altitudes, where it is colder. This will significantly change the alpine ecosystems at lower altitudes and reduce these important habitats. The winter snowfall also contributes a significant 29 per cent of the water flowing into the Murray–Darling Basin. Less precipitation in the alpine regions will have a significant impact on ecosystems downstream.

Figure 4.28: Sparse snow cover at Perisher Ski Resort, New South Wales

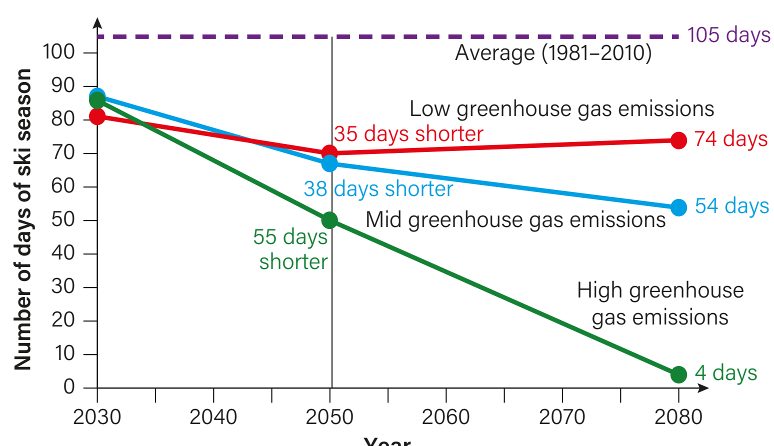


Figure 4.29: Projected trends in the length of ski seasons, based on the amount of greenhouse gas emissions

Figure 4.30: Tuvalu's capital Fanafuti is located on Fongafale Island, a coral atoll that sits only about 3 m above sea level.

Low-lying islands will disappear

Many Pacific island nations consist of low-lying islands or **coral atolls** that are already experiencing adverse effects of climate change.

- By 2030, sea levels in the Pacific will rise 0.09–0.18 m compared to 1986–2005 levels. Sea levels may rise by 0.20–0.36 m by 2050 and by 0.33–0.63 m by 2070.
- Pacific Islands will experience more hot days, and an increase in sea temperatures, which will affect **coral bleaching**.
- Climate change will result in fewer cyclones, but they will be more intense.

Tuvalu is halfway between Australia and Hawaii. It is the second-lowest lying nation in the world, with most of its nine islands sitting only about 3 m above sea level. By 2050, much of Tuvalu will be below the high-tide mark, and the islands will become uninhabitable in the next 50–100 years.

Tuvalu has experienced a higher sea-level rise than anywhere else: sea levels have risen more than 5 mm a year since 1950, compared to the global average of 1.8 mm. During storms, waves crash over the islands, contributing to coastal erosion and damaging crops and infrastructure. The rising sea water has infiltrated **groundwater**, leaving the population reliant on rainfall for fresh water.

Algae from bleaching coral reefs can be toxic for people who eat fish that have ingested the algae.

Modelling shows the impacts of different emissions scenarios

Scientific modelling shows different scenarios. Modelling considers what will happen if emissions continue to rise (high), if immediate action is taken to significantly reduce emissions (low) and scenarios in between the two.

Modelling is useful because it shows that reducing greenhouse gas emissions will have an impact on climate change. If we reduce emissions, we will see some recovery in alpine ecosystems and the ski seasons and less impact on Pacific island nations.

Learning Ladder

Environmental sustainability

1. Identify four changes that can be expected due to climate change in:
   a Australia's alpine ecosystems.
   b Pacific island nations such as Tuvalu.
2. Describe the effects that rising sea levels are having on Pacific island nations such as Tuvalu.
3. Explain the relationship between increasing greenhouse gas emissions and the rising sea levels being observed in Tuvalu.
4. Discuss how a reduction in natural snowfall could affect the water cycle in alpine areas.
5. Analyse the effect of reducing greenhouse gas emissions on ski resorts or on the Pacific islands.

Problem-solving

see page 425

Select either the Australian alpine ecosystems/ ski resorts or Pacific islands as a case study.

1. Apart from reducing greenhouse gas emissions, propose some strategies that could mitigate some of the problems caused by climate change.
2. Explain the relationship between greenhouse gas emissions and the effects being observed.
3. Discuss some of the major challenges preventing human adaptation to climate change.
4. Assess the impact that relocation of key infrastructure would have on addressing some of the effects of climate change.
5. Evaluate the claim, 'It is too late to do anything about climate change.'

In context

Construct an argument you could present as part of a class debate on this topic, 'The use of fossil fuels must be banned by 2035.'

Success criteria

- I can discuss how data can be used to evaluate the impact of climate change.

4·10 ▸ Environmental pollution

Learning intention

At the end of this lesson, I will be able to describe the causes of environmental pollution and discuss its implications.

Key terms

biodegrade: to degrade naturally through the action of microorganisms

eutrophication: an excess of nutrients in a water body that leads to excessive algal growth

photosynthesis: the chemical reaction that occurs in the chloroplasts of plants and algae to convert carbon dioxide and water into glucose and oxygen

Content group: Alternative resource use and recycling

Environmental pollution is the addition of any substance or form of energy to the environment at a rate faster than it can be dispersed, decomposed or recycled. Pollution is a significant issue in ecosystems because it disrupts natural habitats and processes.

Plastic pollution affects aquatic ecosystems

Between 19 and 23 million tonnes of plastic waste end up in the world's waterways every year, polluting rivers, lakes and the oceans. Plastic pollution has big impacts on aquatic ecosystems, from killing wildlife and hindering natural processes, to entering the food chain.

Plastic is a versatile material – it is cheap, flexible and strong and has a wide range of uses as an alternative to natural materials. Most plastic products are designed for single use only, do not **biodegrade**, and easily make their way into the environment.

When plastics enter the oceans, usually as macroplastics (larger than 0.5 cm in size), they can be mistaken for prey by birds, turtles and other marine animals. The consumption of plastic can kill the animal when it blocks their digestive system. This can result in declining populations and can have a major impact on food webs.

The Great Pacific Garbage Patch is a region of 1.6 million square kilometres in the Pacific Ocean between Hawaii and California. Converging ocean currents bring plastic debris to the region. Most of it is small and difficult to see; however, larger items of plastic sometimes converge.

Figure 4.31: This young albatross died from consuming plastic pollution that it mistook for food.

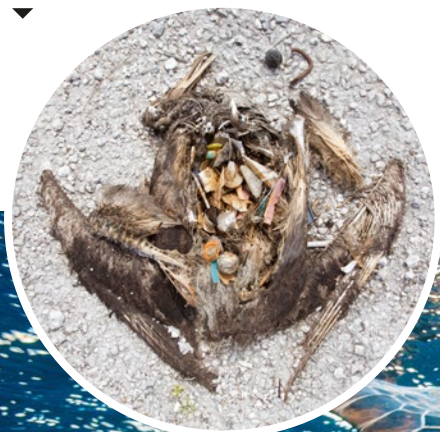


Figure 4.32: Sea turtles can mistake plastic bags for their usual prey of jellyfish.

Plastic items break up into smaller and smaller pieces the longer they are in the environment. Microplastics are less than 5 mm in diameter and can be consumed by small fish and filter feeders and accumulate up the food chain. Microplastics have been found in Antarctic ice, in the bodies of deep-sea creatures, in the sands of remote beaches, and even in humans.

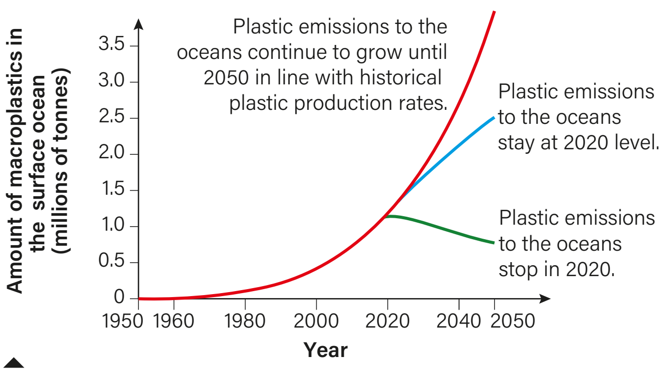


Figure 4.33: Macroplastics are buoyant plastic materials greater than 5 mm in diameter. The graph shows three scenarios for future global accumulation in the surface ocean.

Eutrophication is caused by excess nutrients

Eutrophication is caused by the build-up of excess nutrients such as nitrogen and phosphorus in bodies of water. This sets off a chain reaction in the ecosystem that can significantly affect the overall health of the waterway. Often, the source of the excess nutrients is poor farming practices but it can also come from industry. When nutrients build up, they can cause rapid algal growth (blooms)

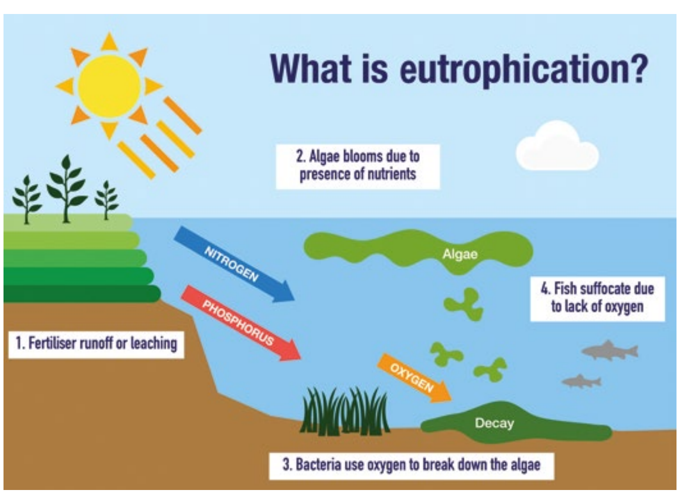


Figure 4.34: Eutrophication is caused when excess nutrients pollute waterways.

across the surface of the water. The algal bloom blocks sunlight from reaching other aquatic plants, reducing photosynthesis and the amount of oxygen being dissolved deeper in the water. Overnight, the level of oxygen drops even further, as there is no photosynthesis, which can kill fish and other aquatic animals. When the algae and plants die, the decomposition releases more carbon dioxide into the water, and the decomposers use up all of the oxygen that is left. This can result in a change in the water's pH as well as an absence of oxygen, forming dead zones.

Learning Ladder

Environmental sustainability

1. Identify three non-renewable resources discussed in this section.
2. Describe some of the effects that plastic pollution has on natural ecosystems.
3. Explain why high levels of nutrients in an aquatic ecosystem can have a negative impact.
4. Discuss the impacts of eutrophication on ecosystems.
5. Analyse how our reliance on plastics has affected the natural world.

Analysing data and information *see page 420*

Consider the data in Figure 4.33.

1. Describe the trend in the amount of macroplastics in the surface ocean shown in the graph.
2. Propose an explanation for the trend you described in Question 1.
3. If there is no change in the management of plastic products, predict the amount of macroplastics in the surface ocean in 2030.
4. Describe what data would have needed to be collected to ensure the graph in the figure is reliable.
5. 'The amount of macroplastics is an indication of the amount of microplastics in the ocean.' Evaluate this statement.

In context

Discuss why algal blooms in urban lakes often follow periods of intense rainfall.

Success criteria

- I can describe the causes of plastic pollution and discuss its implications.
- I can describe the causes of eutrophication and discuss its implications.

4·11 ▶ First Nations Peoples' sustainable harvesting practices

Learning intention

At the end of this lesson, I will be able to understand how caring for Country by First Nations Peoples has contributed to sustainable harvesting practices for millennia and how this sustained the pre-colonial population of the Australian continent and adjacent islands.

Key terms

Dreaming: a complex term that describes the ways that Aboriginal and Torres Strait Islander Peoples relate to themselves, each other, and the human and more-than-human realms

tuber: the rhizome part of a plant, which forms underground and is often nutrient rich

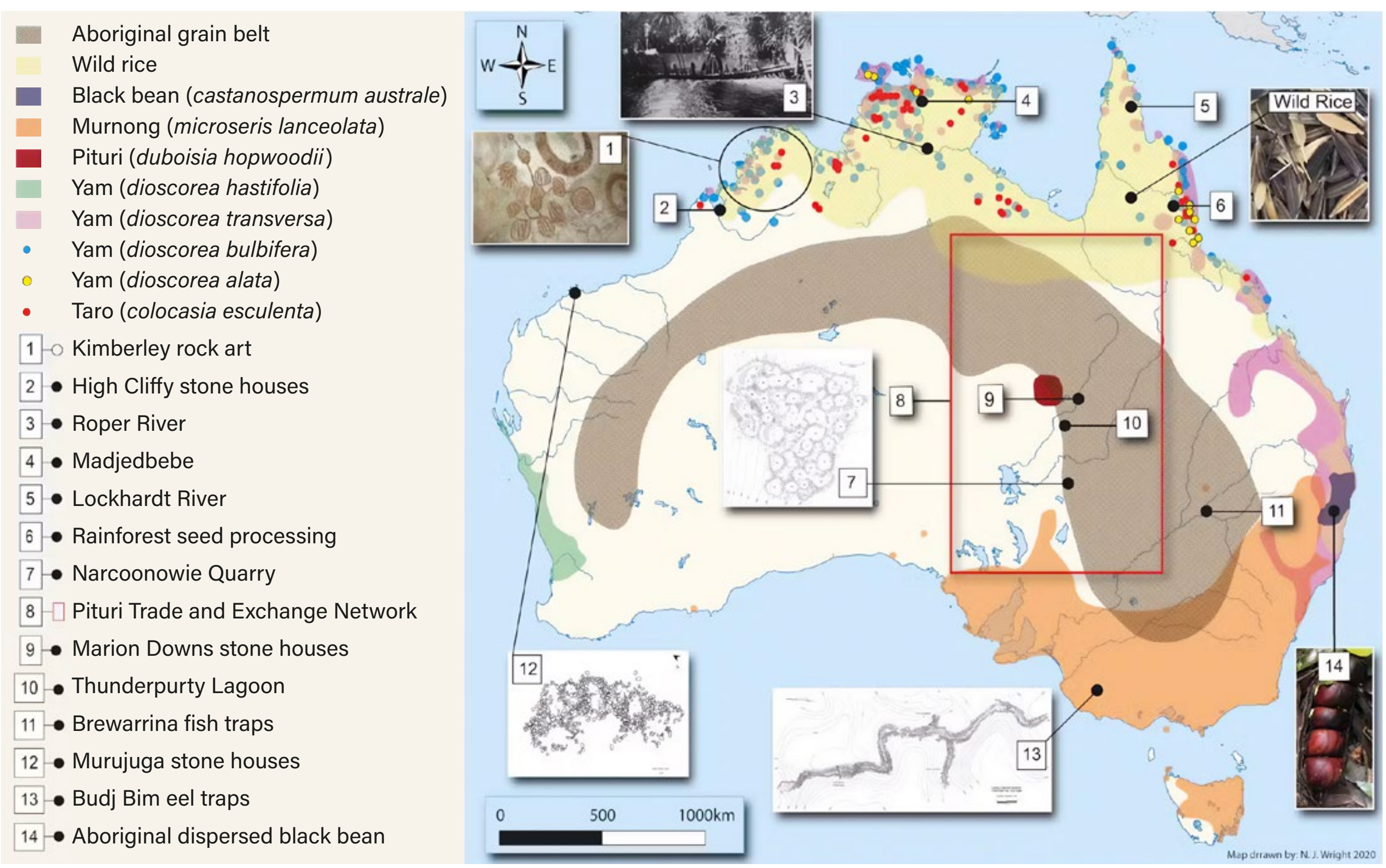
Content group: Alternative resource use and recycling

Before colonisation, First Nations Peoples managed the landscapes and waterscapes to ensure that there was enough nourishing food for the present and into the future.

Caring for Country involves sustainable harvesting

For many First Nations Peoples, the concept of caring for Country has always been a priority and is often central to individual and community concepts of **Dreaming**. For millennia, the complex scientific knowledges that have informed the specific practices of caring for Country have been taught through story, song and dance. This includes the practice of sustainable harvesting, where the land and waterscapes are modified to support production, and the fundamental principle of taking only what is needed, to ensure future supply.

Figure 4.35: This map shows the areas where farming and agriculture flourished across the Australian continent before European colonisation.



First Nations Peoples harvested crops sustainably

Murnong **tubers** were eaten widely across the south-eastern part of the Australian continent for thousands of years. The Murnong (yam daisy) was brought to the brink of extinction by European livestock, which compacted the soil and ate its leaves.

Aboriginal famers farmed this crop sustainably by:

- allowing enough plants to go to seed to sustain future harvests. Aboriginal farmers regularly tilled the soil to aerate it, and to allow the seeds to germinate and the yams to form underground
- taking only one or two tubers per plant and replanting the rest for future harvests.

Fire was used to reduce tree coverage, and stone weirs were used to keep water in the environment for longer so it could be better absorbed by the soil. This created large areas of open pasture and allowed many native grains to be sustainably harvested. Grain was produced in large parts of the Australian continent that today are considered to be arid and unsuitable for grain farming.

First Nations Peoples practised sustainable aquaculture

First Nations Peoples used complex aquacultural harvesting practices. A common technique was to link seasonal phenomena observed on land to unrelated phenomena observed in waterways. For example, many Torres Strait Islander stories tell of how the breeding and migration cycles of many water species relate to the yearly or seasonal appearance of specific constellations in the night sky. Other stories tell of how the flowering of a particular plant coincides with the spawning season of a specific freshwater crustacean. When the flower is blooming, removing the crustacean from the waterway would be unsustainable because it would interrupt the breeding cycle and result in fewer crustaceans for the next season.

Current projects are re-engaging with First Nations knowledges

Across Australia, many projects are re-engaging with First Nations knowledges of sustainable harvesting practices. For example, Indigenous rangers work directly with Country to care for it and apply the complex scientific understandings of the Dreaming stories.

Learning Ladder

Environmental sustainability

1. Identify the impact the introduction of non-native plants, animals and insects has on native sources of food.
2. Describe two ways in which the land and waterscape of the Australian continent were modified in order to expand where native grains could be farmed.
3. Explain why only some Murnong tubers were taken from each plant during harvest. How did this affect the sustainability of the Murnong?
4. Discuss the factors that show it is the right time to harvest turtles, dugongs and plant gardens in the Torres Strait.
5. Analyse how the introduction of European livestock nearly caused the Murnong to become extinct.

Problem-solving

see page 425

1. Describe what Aboriginal farmers needed to do to the soil so that the Murnong would grow.
2. Explain the link between fire use and available areas for planting crops. What problem did this solve?
3. What programs are being implemented in contemporary Australia to help care for Country? How are these programs helping to manage and improve the land?
4. Sustainability was not the primary focus when teaching First Nations children about Country. Assess the use of traditional practices of caring for Country as an effective way to embed sustainability practices in land management.

In context

Local Aboriginal Land Councils are organisations that work across all of New South Wales. Conduct research into your local Aboriginal Land Council, and explain how it assists with land management and implementing sustainable land-management practices.

Success criteria

- I can understand how unrelated phenomena can help to inform how to care for Country and harvest food sustainably.
- I can understand some of the techniques used by Aboriginal and Torres Strait Islander farmers to ensure that the harvesting of food was sustainable.

4.12 ▶ Improving resource use

Learning intention

At the end of this lesson, I will be able to discuss some strategies that will improve our use of resources.

Key terms

crude oil: a naturally occurring liquid fossil fuel that can be refined to produce many different chemicals

landfill: disposal of waste by burying it

Investigation 4.12

Making bioplastic, page 528

Content group: Alternative resource use and recycling

We need to use resources sustainably so they are available for future generations. Sustainable use of a resource could mean reducing its use or finding an alternative. It could mean ensuring an item can be reused, or recycling the materials into a new product. Reducing the amount of waste that goes to landfill is a good indicator that resources are being used sustainably.

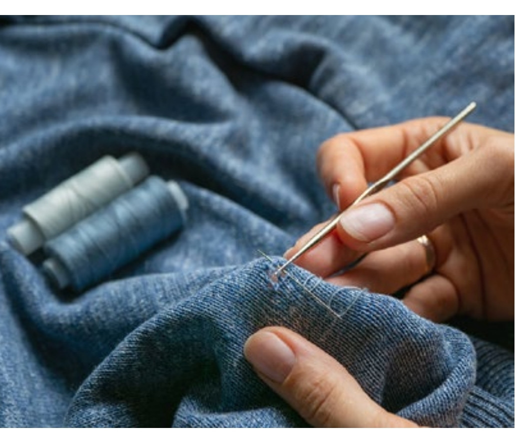
Reduce the amount of resources we use

Reducing the use of a resource ensures it is available for longer. We need to carefully manage non-renewable resources, such as metals and fossil fuels, so they are available for future use. Government measures could encourage us to reduce our use of the resources, find alternative materials to use in their place, or be mindful of how much we consume.

Replacing conventional plastics made from chemicals derived from **crude oil** with those made from plant materials reduces reliance on fossil fuels.

Australians produce a large amount of waste. Each year, they throw out more than 3.3 tonnes of food, with the average family throwing out one out of every five bags of groceries they buy. Cheap clothing and fast fashion trends result in half a million tonnes of textile waste going into **landfill**. Many products are made for single use or are packaged in plastic that cannot be recycled. More than 1 billion single-use coffee cups are used each in Australia, with most of them going into landfill. By changing our buying habits, we can reduce the amount of resources we use and the amount of waste that goes to landfill, but also reduce the use of resources that are consumed in the manufacture of these items.

▲ **Figure 4.36:** More than 1 billion single-use coffee cups are used in Australia every year.



▲ **Figure 4.38:** Repairing items can allow them to be reused.

Figure 4.37: The fast fashion industry contributes to a large amount of textiles going to landfill.

Reuse items to reduce waste

Reusing items reduces waste by allowing a resource to be used for longer before it is disposed of or recycled.

Some items are designed and made to be used again and again, such as reusable coffee cups and glass bottles, and replace the need for single-use items.

Repairing items can extend their useful life. Some communities have repair cafes where members share their knowledge and tools to repair damaged items, rather than disposing of them and buying new ones.

Some clothing companies are providing repair services to help people extend the life of their clothes, as well as offering options for people to buy and sell their clothes second-hand. This helps to reduce the amount of textile waste in landfill.

Recycle materials for another purpose

Recycling involves processing items to obtain the materials they are made from so they can be used for another purpose. Paper, cardboard, plastic bottles and aluminium cans can all be recycled.

Professor Veena Sahajwalla is a renowned materials scientist who is developing methods for extracting resources from waste, enabling the waste product to be reused. Green steel technology is one of her best-known inventions. Traditionally, steel is made by mixing iron with coal in a furnace at very high temperatures – the addition of the carbon atoms makes the metal much stronger. Professor Sahajwalla pioneered a process that replaces the coal with rubber car tyres (which are also high in carbon), resulting in steel that is produced without the need for fossil fuels.

Figure 4.39: Professor Veena Sahajwalla has pioneered the use of old tyres as a resource, replacing the need for using coal in the production of steel.

Learning Ladder

Environmental sustainability

1. Identify some examples of resources that can be easily:
   a reduced.
   b reused.
   c recycled.
2. Describe the difference between reusing and recycling an item.
3. Explain the impact of using tyres as an alternative to coal in the steel-making process.
4. Paper is made from fibres obtained from trees. Discuss the effect that paper recycling has on the management of this natural resource.
5. 'Reduce, reuse and recycle' is a common catchphrase. Evaluate which of these is the most effective in the sustainable management of resources.

Problem-solving

see page 425

Complete a diary that records the resources you use and the waste you produce (what you throw out) over a set period (e.g. 1 day or up to 1 week).

1. Propose a resource that you could easily reduce your use of.
2. Explain why you selected this resource.
3. Consider the waste you produce. Brainstorm some solutions that would enable you to reduce this waste.
4. Assess your solutions. Identify the solution that you think would have the biggest impact. Justify your response.
5. 'Sustainability is the responsibility of every individual, every day.' Evaluate this statement by using evidence.

In context

Professor Veena Sahajwalla leads the University of New South Wales's Centre for Sustainable Materials Research and Technology (SMaRT@UNSW). One of the other important developments that have come from this centre is green ceramics. Conduct research to find out what waste is used to create this material.

Success criteria

- I can discuss some strategies that reduce our use of resources.
- I can discuss some strategies that improve our use of resources.

4.13 ▸ How materials are recycled

Learning intention

At the end of this lesson, I will be able to describe how plastic and aluminium products are recycled.

Key terms

polymer: a long-chain molecule (usually carbon based) made up of many small repeating units

recycle: to convert waste into reusable materials

Content group: Alternative resource use and recycling

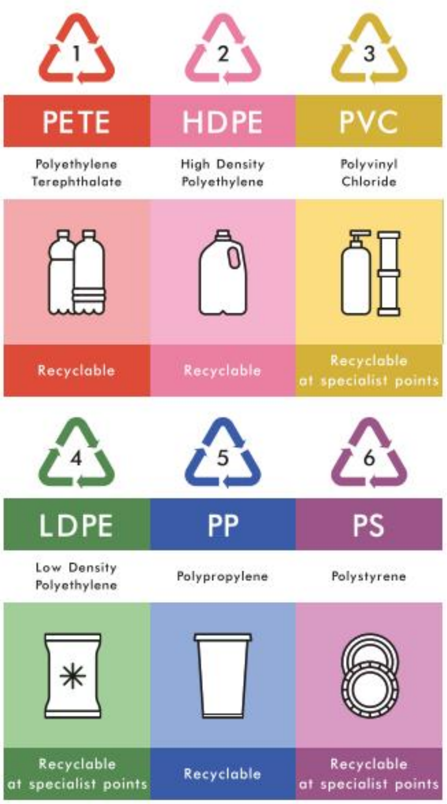


Figure 4.40: Plastic identification codes are used to identify the type of plastic an item is made from.

Recycling not only removes an item from landfill, allowing a material to be used again, but can also use less energy than making an item from raw materials. Recycling processes involve sorting items to ensure there is no contamination, before processing them into a material that can be used to make new products. Not all items are straightforward to recycle, and so innovative processes need to be developed.

Plastic recycling reduces waste and saves energy

Most plastics are made from **polymers** – long-chain molecules – and originate from crude oil.

There are many different types of plastic, and the type depends on how it can be recycled. You can identify the type of plastic an item is made of by the plastic identification code stamped on it (Figure 4.40).

The advantages of recycling plastic include:

- it reduces plastic waste
- it reduces energy use – making a plastic product from recycled materials uses about three times less energy than making it from new plastic.

Plastics can be recycled chemically or mechanically. Mechanical recycling is more common and involves sorting the plastic by type, washing it, then shredding it into pellets to be melted down and reused.

However, there are limitations to mechanical recycling:

- It requires sorting plastic items to avoid impurities.
- Plastic loses quality over time because the shredding can shorten the length of the polymer. This means that the plastic cannot be reused indefinitely to create the same type of product, but instead will be down-cycled for use in products that use a lower quality plastic.

Chemical recycling uses chemical reactions to break down the plastic polymers into monomers that can then be used to make new polymer chains. The advantage of this process over mechanical recycling is that the quality of the plastic can be maintained and so in theory the plastic is infinitely recyclable. Chemical recycling processes are still relatively new and expensive and use a large amount of energy.

Aluminium is easily recycled

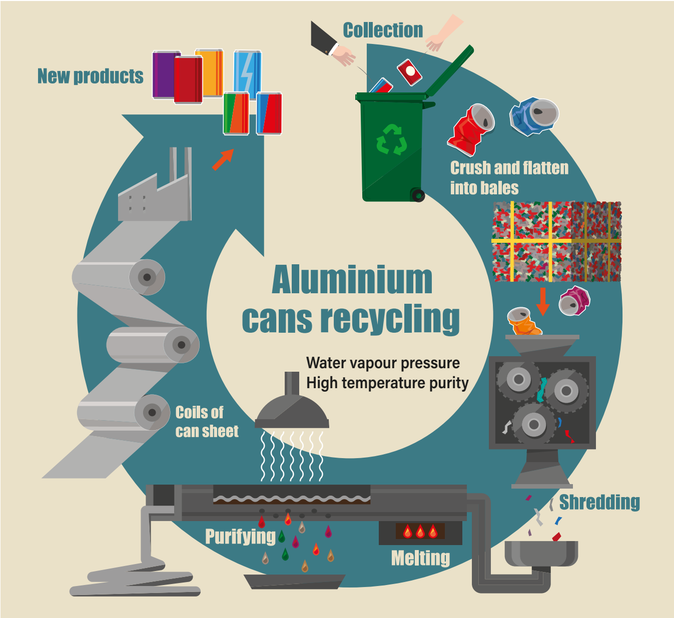
Aluminium is the Earth's most abundant metal and one of the most durable and versatile. It is used in drink cans and kitchen foil, in building materials such as window frames, and in car and aeroplane parts. More than 75 per cent of the aluminium that has been extracted from Earth is still in use today because it is so easily recycled. Making an object

Figure 4.41: Shredded plastic produced during mechanical recycling

Figure 4.42: Aluminium is melted down in furnaces as part of the recycling process.

from recycled aluminium uses 5 per cent of the energy required to make it from new aluminium.

Sorting of aluminium waste ensures there is no contamination before the aluminium items are crushed into bales. If the aluminium has a coating, it will be put into a rotary furnace to burn the coating off. It is then melted down in a furnace. The molten aluminium is cast into bricks called ingots for reuse.



▲ **Figure 4.43:** The aluminium recycling process involves sorting, crushing, melting and recasting.

Innovative recycling is needed for complex products

Recycling is straightforward when a product is made from one material; however, many items that we use are made up of many different types of materials. We need to develop more innovative recycling processes for complex items such as phones and computers.

Learning Ladder

Environmental sustainability

1. Identify if plastic and aluminium are renewable or non-renewable resources. How do these resources affect the natural world?
2. Describe the process used to recycle
   a plastic. **b** aluminium.
3. Explain the advantages of recycling plastic by chemical processes.
4. Discuss the impact on the environment of not recycling plastic products.
5. Analyse the importance of recycling for the sustainable use of aluminium.

Problem-solving

see page 425

Imagine your school does not have separate bins for waste and recycling, but the student council wants to implement recycling bins. They want to make sure they collect only plastic and aluminium items that can be recycled and not have any contamination.

1. Brainstorm to suggest ways this could be done.
2. Select one of your suggestions and use your understanding of the recycling process to explain why it is important to implement.
3. Rank your suggestions in order of most realistic to least realistic to implement at school.
4. Assess the pros and cons of your most realistic suggestions.

In context

Discuss the advantages and disadvantages of using plastic from soft-drink bottles to make fabric for clothing.

Success criteria

- I can describe how plastic products are recycled.
- I can describe how aluminium products are recycled.

4.14 ► Environmental sustainability in context

Learning intention

At the end of this lesson, I will be able to explain how human activity is affecting the Great Barrier Reef.

Key terms

symbiotic relationship: an ecological relationship where both parties cannot survive without the other

zooxanthellae: algae that live in coral tissues

Content group: Environmental sustainability in context

▲ **Figure 4.44:** The Great Barrier Reef is the world's largest coral reef system.

Coral reefs occur in shallow tropical seas and are among the most diverse ecosystems on Earth. The vast structures built by coral polyps provide homes to thousands of species, many of which are important food sources for humans. The Great Barrier Reef is the world's largest coral reef system. Situated off the coast of Queensland, it extends more than 2000 km from K'gari/Fraser Island in the south to the Torres Strait in the north. Over recent decades, the Great Barrier Reef has experienced significant damage due to human activity and climate change.

High sea temperatures cause coral bleaching

Coral reefs are calcium carbonate structures built by coral polyps that live in a **symbiotic relationship** with a type of algae called **zooxanthellae**. The algae photosynthesise, providing the coral with glucose in exchange for a place to live. They provide the coral with about 90 per cent of its energy.

Coral bleaching occurs when the coral becomes stressed and expels the algae, leaving the white skeleton behind. The leading cause of coral bleaching is sea temperature rise. Corals grow best at sea temperatures of 23–29 °C, and an increase of about 1 °C over approximately 4 weeks is enough to cause the corals to bleach. If the temperatures quickly return to normal, the coral can recover, but if temperatures stay high for 8 weeks or more, the coral will die.

The Great Barrier Reef first experienced coral bleaching due to sea temperature rise in 1998. It has experienced six bleaching events since – in 2002, 2016, 2017, 2020, 2022 and 2024.

Continuing high temperatures will cause many coral species to disappear from the reef. Algae from bleaching coral reefs is toxic for people who eat fish that have ingested the algae.

Figure 4.45: The Great Barrier Reef is home to thousands of species that depend on the coral to survive.

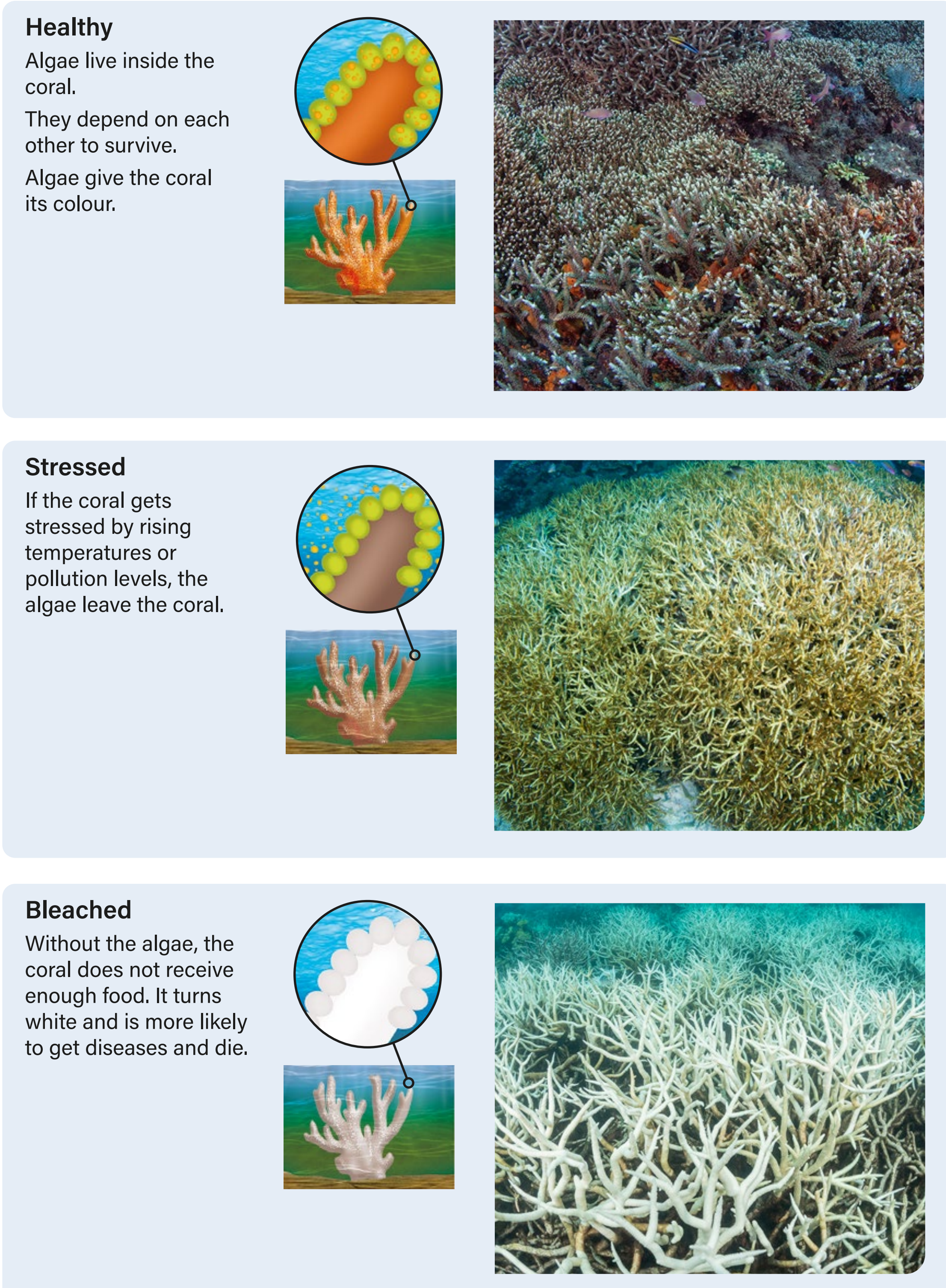


Figure 4.46: Coral bleaching occurs when coral becomes stressed and expels its symbiotic algae.

Acidification of oceans is harming coral

We saw in Section 4.8 that increased levels of carbon dioxide dissolving in the water are making the oceans more acidic. The increased levels of carbon dioxide in the atmosphere are a result of burning fossil fuels.

Coral skeletons are made of calcium carbonate. When carbon dioxide is added to ocean water, carbonate ions bond with excess hydrogen ions instead of with calcium ions. This means that less calcification occurs, and under these conditions corals cannot make their skeletons. If the water becomes too acidic, the skeletons will dissolve.

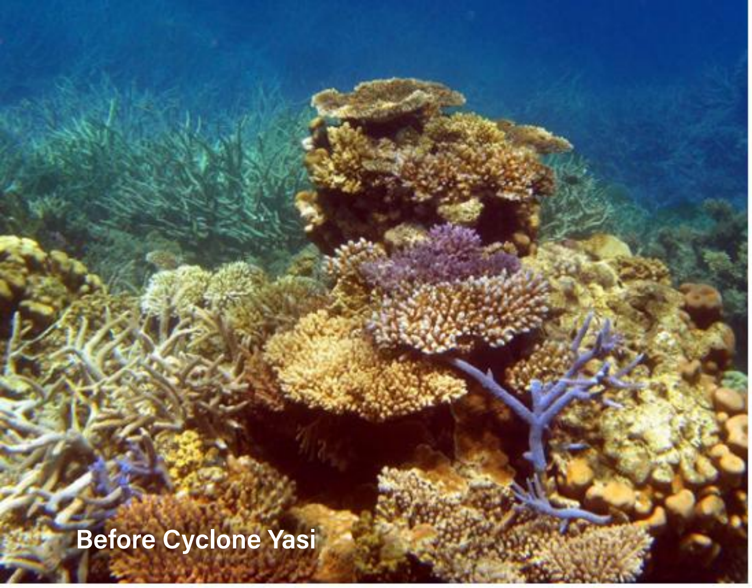


Figure 4.47: Cyclone Yasi caused extensive damage to the Great Barrier Reef in 2011.

Cyclones damage reefs

Storm surges damage beaches, dunes and urban areas. Floodwaters pick up topsoil and transport it into the oceans.

The intense wind and wave action of a cyclone can kill organisms and damage habitats both on land and in the ocean. Corals are damaged by high-energy waves, and further damage occurs when sediments from the land are washed into the ocean near the reef.

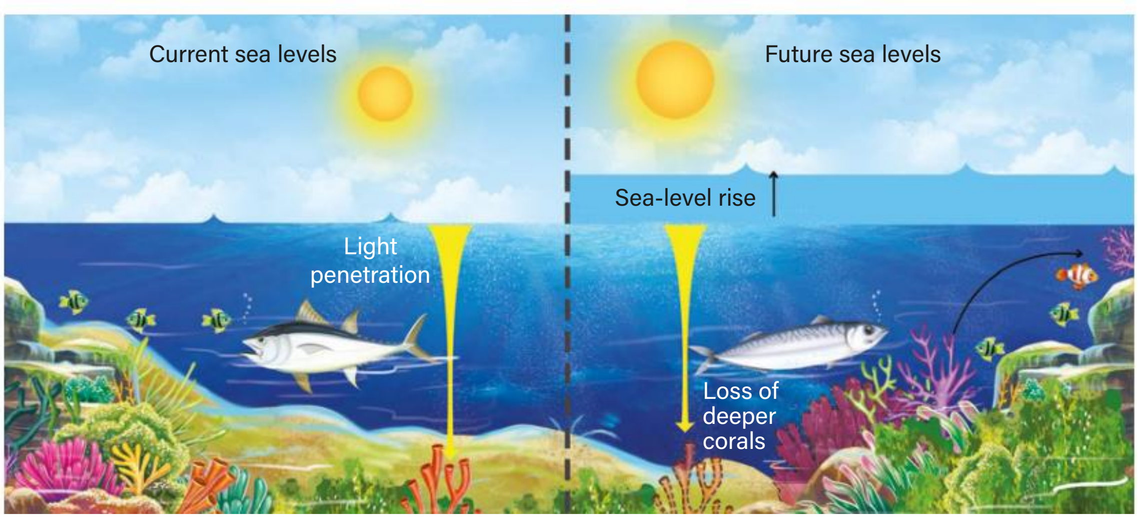
In 2011, Cyclone Yasi – one of the most powerful cyclones to affect Australia in recorded history – caused significant damage to the Great Barrier Reef. Wind gusts of 290 km h^{-1} were reached and about 300 km of the reef was affected to varying degrees. When coral reefs are harmed or destroyed, it can have significant consequences for coastal communities. They become more vulnerable to storms and even to the regular force of waves. Recovery can take decades, and the reef's long-term survival requires ongoing scientific monitoring and conservation measures.

Rising sea levels will cause coral reefs to disappear

Sea levels are important for the distribution of species and habitats in oceans. Many marine organisms have adapted to survive at a certain depth. Coral reefs require shallow water so that enough light can penetrate for photosynthesis to occur. If sea levels rise very slowly, corals will grow towards the surface and the reefs will migrate into shallower water over time.

Since 1991, sea levels have risen about 3 mm per year on the Great Barrier Reef. Currently, this small change is not affecting the reefs, as the corals can grow faster than this. However, sea levels are predicted to begin to rise much faster and the corals will not be able to keep up. Many reef communities will disappear because they will be unable to reestablish themselves quickly enough.

Figure 4.48: When sea levels rise, corals in deeper water cannot survive because they do not receive sufficient sunlight. Corals might establish and grow in shallower waters, but this may not happen quickly enough.



Pollution damages reefs

A growing human population along the Queensland coast is producing more pollution that is damaging the Great Barrier Reef. Development along coastlines is often accompanied by clearing of forests, including mangrove habitats. This clearing has increased the amount of sediment that runs into the ocean during large rain events. Sediments make the water cloudy, blocking sunlight, and settle on and cover the coral. Nutrient run-off from farms encourages algal growth that can smother coral and seagrass beds. Rubbish such as plastic, and fuel from tourists' boats, are also having an impact on the reef.

Figure 4.49: Sediment is carried out of the Burdekin River south of Townsville after a flood event in 2010.

Learning Ladder

Environmental sustainability

1. Identify the correct ecological relationship between coral polyps and zooxanthellae.
   - **A** The coral is the predator and the zooxanthellae is the prey.
   - **B** They have a symbiotic relationship.
   - **C** The zooxanthellae is a parasite on the coral.
2. Describe why corals live in shallow water.
3. Explain the relationship between coral bleaching and sea temperature.
4. Discuss some of the issues relating to increased coastal development on the Great Barrier Reef.
5. Analyse how increased carbon dioxide in the atmosphere is affecting coral reefs.

Problem-solving

see page 425

1. Marine biologists are undertaking research to develop corals that have a higher heat tolerance. Brainstorm a list of pros and cons for the introduction of such corals.
2. Explain what you could expect to happen to the biodiversity of the Great Barrier Reef if heat-resistant corals were introduced and if ocean temperatures continue to rise.
3. Propose one way that the heat-resistant coral could be used, while maintaining the existing biodiversity of the Great Barrier Reef.
4. Many establishments in Australia have introduced paper straws to help reduce water pollution in areas like the Great Barrier Reef. Assess the effectiveness of this pollution reduction strategy.

Success criteria

- I can describe how increased sea temperature leads to coral bleaching.
- I can describe how sea-level rise will affect the Great Barrier Reef.
- I can describe the impact of pollution on the Great Barrier Reef.
- I can describe the effects of cyclones and ocean acidification on coral reefs.

► Environmental sustainability summary

Sustainability

The principles and goals of sustainability are to:

- promote the responsible and ethical use of Earth's resources
- protect the environment
- ensure a high quality of life for present and future generations.

- We depend on the natural environment to survive. Our food is sourced from plants and animals; aquatic ecosystems provide clean drinking water; and photosynthesis creates oxygen.
- Biodiversity is important for healthy ecosystems. Natural ecosystems are more biodiverse than those changed by humans.
- The United Nations Sustainable Development Goals recognise that actions taken in one area will affect other areas.

Western views on sustainability:

- Members of the United Nations have agreed that sustainability is a priority.
- People are encouraged to work together to ensure quality of life for current and future generations.
- Natural and non-renewable (finite) resources need to be managed carefully.
- Scientific knowledge is used to conserve ecosystems and preserve biodiversity.

First Nations Peoples' views on sustainability:

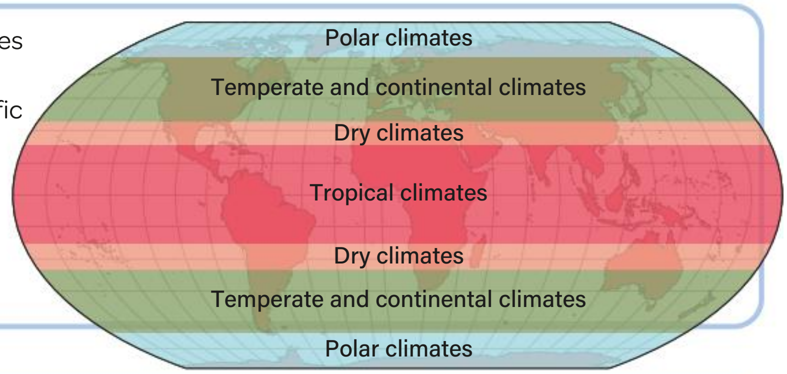
- Caring for Country is a priority and a way of life.
- People have a responsibility to care for the future just as much as we care for the present.
- Country needs to be cared for as we would care for friends, family and our community.
- Caring for Country includes sharing knowledge and practices to care for Country and thereby conserve ecosystems and preserve biodiversity.

Climate science

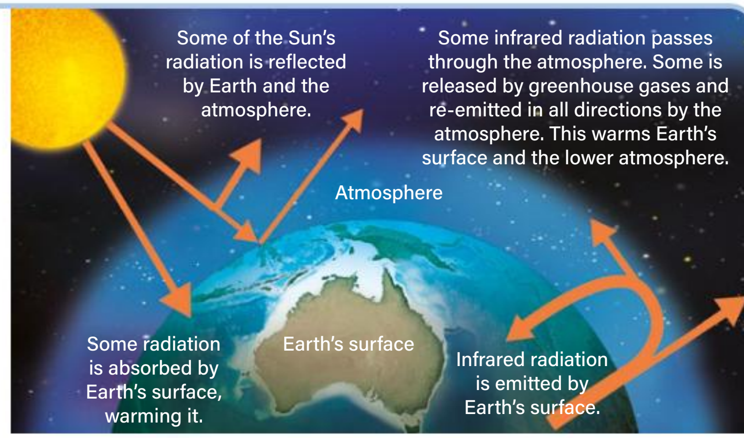
The difference between climate and weather is a matter of time.

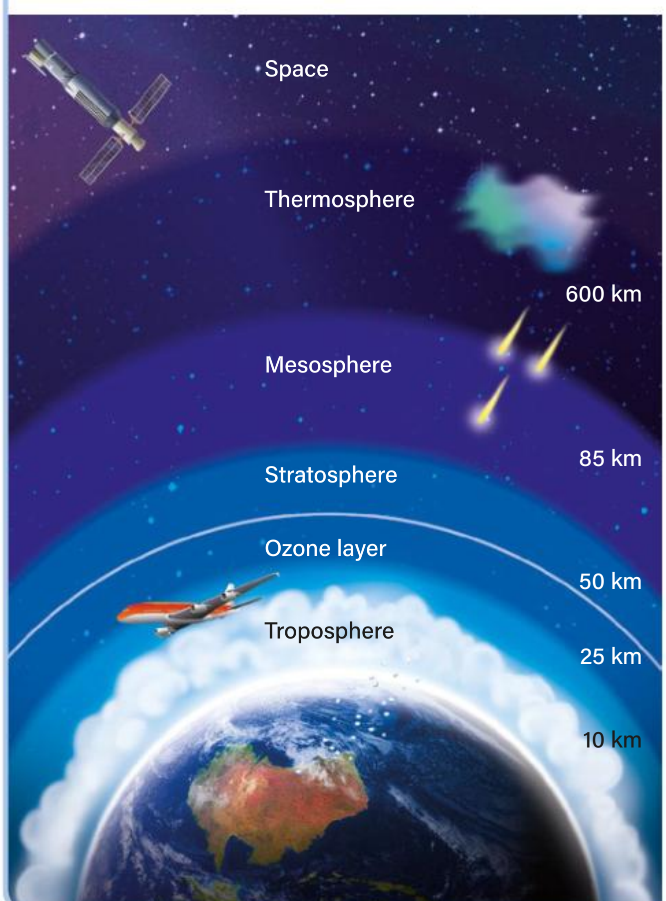
- **Weather** is what is happening in the atmosphere at a specific place over a short period.
- **Climate** is average weather patterns at a specific location or region over a long period.

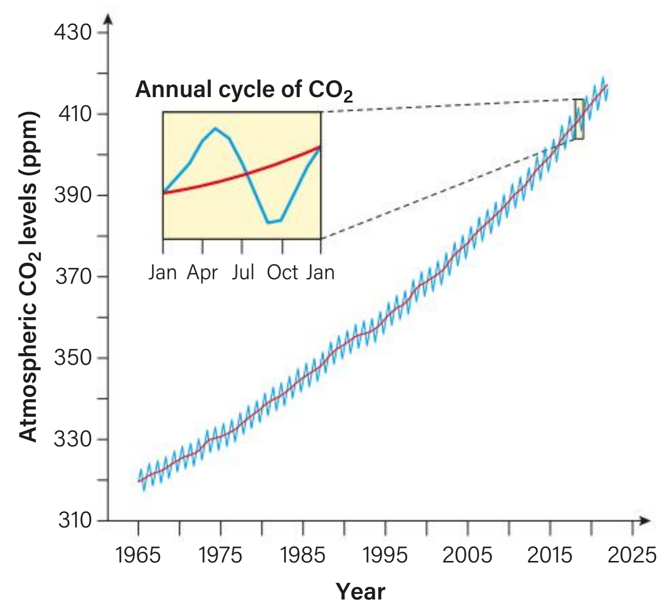
Climate zones are regions with a specific climate.



- The atmosphere is a layer of gas 600 km thick that surrounds Earth. It is made up of four layers and protects our planet from harmful radiation.
- The atmosphere is made up of about 78 per cent nitrogen, 21 per cent oxygen, 0.93 per cent argon, 0.048 per cent carbon dioxide and very small amounts of other gases, including water vapour.
- Greenhouse gases, such as carbon dioxide, water vapour and methane, trap radiation energy produced by the Sun to keep Earth's surface warm. This is called the greenhouse effect.



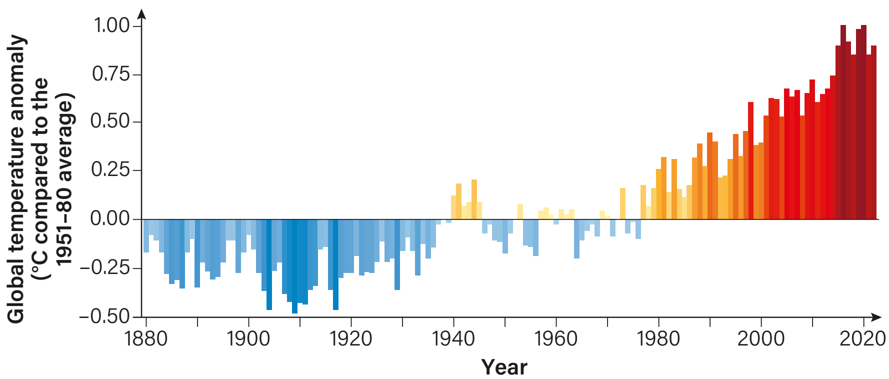




- Human activity that adds additional greenhouse gases into the atmosphere, such as by the burning of fossil fuels, has enhanced the greenhouse effect, resulting in an increase in atmospheric temperatures.
- Data from ice cores and atmospheric sampling shows that the concentration of carbon dioxide in the atmosphere is rapidly increasing compared to the past.

- Strategies to reduce greenhouse gas emissions include:
  - generating electricity from renewable sources
  - switching to more energy-efficient appliances
  - switching to hybrid or electric vehicles
  - changing agricultural practices to reduce methane production by livestock.
- Challenges in reducing greenhouse gas emissions include:
  - Fossil fuels are the cheapest form of energy.
  - The mining of fossil fuels contributes considerable amounts of money to the economy.
  - New technologies are expensive.
  - Processes for building new technologies can damage the environment.

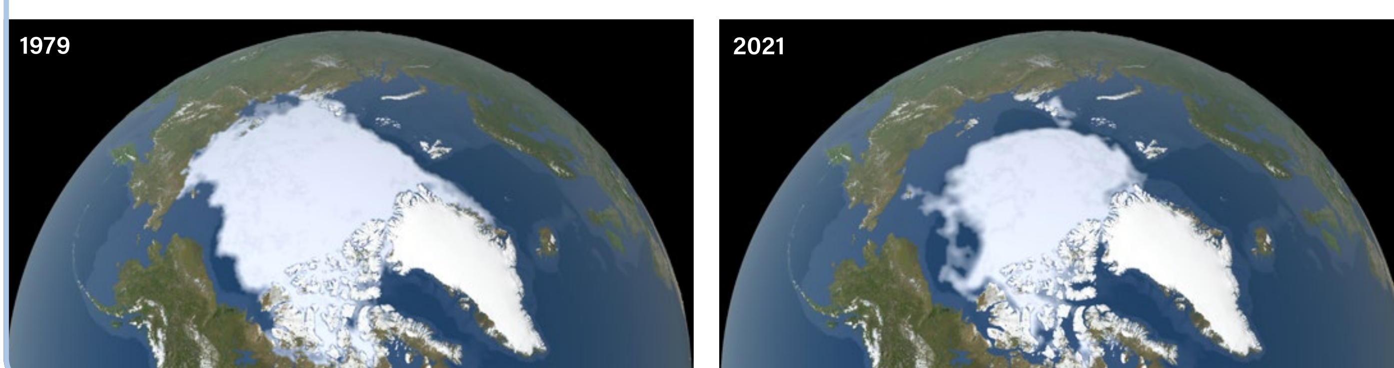
Impacts of present-day climate change



- The global climate is changing, driven by an increase in atmospheric temperature.
- Long-term data shows that Earth's average temperature has increased since 1880.
- This is influencing weather patterns, sea levels, ocean temperatures, and the presence of ice at the poles.

Effects of climate change include:

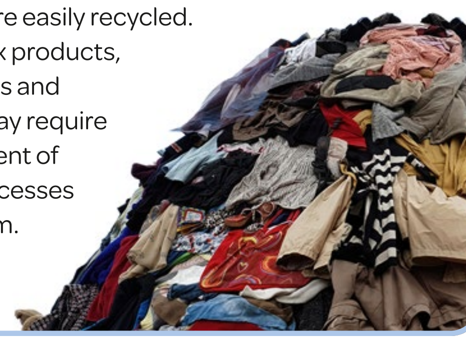
- increased evaporation and precipitation
- increased acidification of the oceans, resulting in bleaching of coral reefs
- more frequent heatwaves and bushfires
- reduced presence of ice at the poles, contributing to rising sea levels
- the loss of habitats (e.g. from reduced snow cover) of sea ice in the Arctic, and reduced biodiversity.



Alternative resource use and recycling

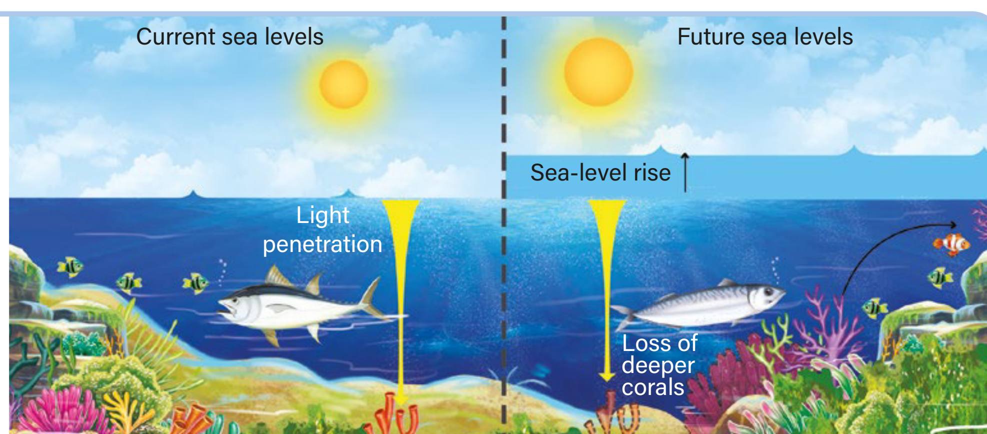
- Environmental pollution is the addition of any substance or form of energy to the environment at a rate faster than it can be dispersed, decomposed or recycled.
- Pollution is a significant issue in ecosystems because it disrupts natural habitats and processes
- When plastics enter the oceans, they can be mistaken for prey by birds, turtles and other marine animals.
- The build-up of excess nutrients, such as nitrogen and phosphorus, in waterways can lead to eutrophication.

- First Nations Peoples' sustainable harvesting and land-management practices include:
  - taking only what is needed, to ensure future supply
  - using fire to reduce tree coverage
  - constructing stone weirs to keep water in the environment for longer, for better absorption by the soil
  - practising sustainable aquaculture to ensure future supply.
- We need to use resources sustainably, so they are available for future generations. Some strategies include:
  - reducing the amount of the resource that is used, so there will be more for future generations
  - reducing support of the fast fashion industry, which contributes to large amounts of textiles going to landfill
  - reusing or mending an item to extend its useful life and reduce waste
  - recycling materials into a new product or for another purpose.
- Recycling removes items from landfill and allows materials to be used again. Making a product from recycled materials can also use less energy than making an item from raw materials.
- Plastics can be recycled chemically or mechanically.
- More than 75 per cent of the aluminium that has been extracted from Earth is still in use because it is so easily recycled.
- Not all items are easily recycled. Some complex products, such as phones and computers, may require the development of innovative processes to recycle them.



Environmental sustainability in context

Human activity is causing pollution concern, leading to events including rising sea levels that may destroy ecosystems such as the Great Barrier Reef.



Masterclass

Steps in progression		1	2
Content	Environmental sustainability	Identify sources of plastic pollution.	Describe some of the effects that plastic pollution has on marine organisms.
Processes	Analysing data and information	Use Figure 4.50 to describe the pattern of garbage concentration in the Great Pacific Garbage Patch.	Propose a reason for the pattern of garbage concentration shown in Figure 4.51.
	Problem-solving	Brainstorm some solutions that could be developed to clean up the Great Pacific Garbage Patch.	Explain some of the challenges that are faced by those who want to clean up the oceanic garbage patches.

The Great Pacific Garbage Patch

The world's oceans are linked by flowing ocean currents that transport thermal energy and nutrients around the globe. These currents are vital for marine ecosystems and influence regional climates; however, they also transport pollution.

Gyres are locations where currents converge. The water moves in a circular motion on the outside, while the water in the centre is much calmer. Plastic pollution brought in by currents is trapped inside a gyre, forming oceanic garbage patches. There are oceanic garbage patches in each of the five gyres around the world; however, the Great Pacific Garbage Patch (the North Pacific Gyre), in the Pacific Ocean between Hawaii and California, is the largest at 1.6 million square kilometres (almost twice the size of New South Wales).

While some of the plastic found in the oceanic garbage patches is sourced from items that fall off cargo ships or discarded fishing equipment, most of it is washed out to sea from the land. Plastic in the garbage patches will have travelled thousands of kilometres before becoming trapped.

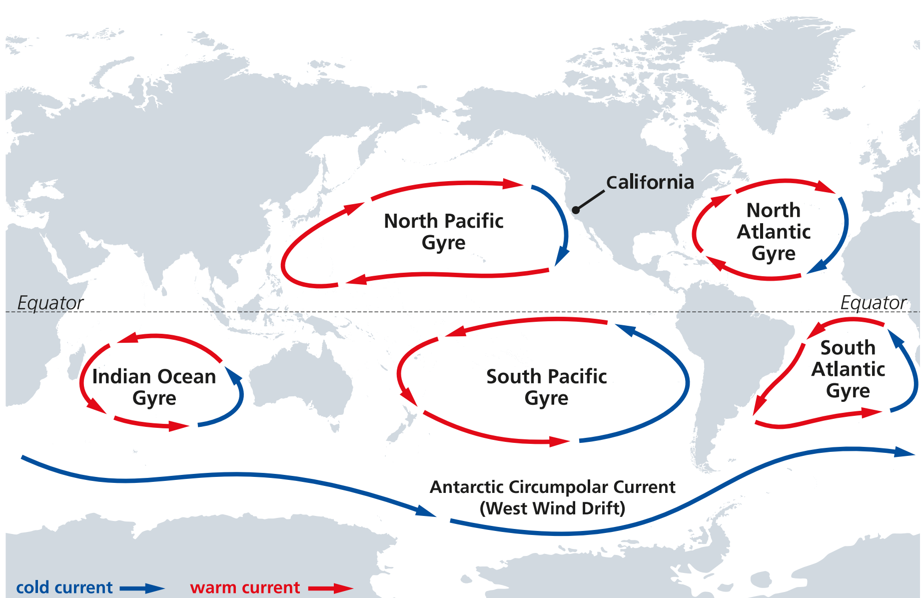


Figure 4.50: Currents converge to form five gyres in the world's oceans. These are locations where plastic pollution accumulates, forming 'garbage patches'.

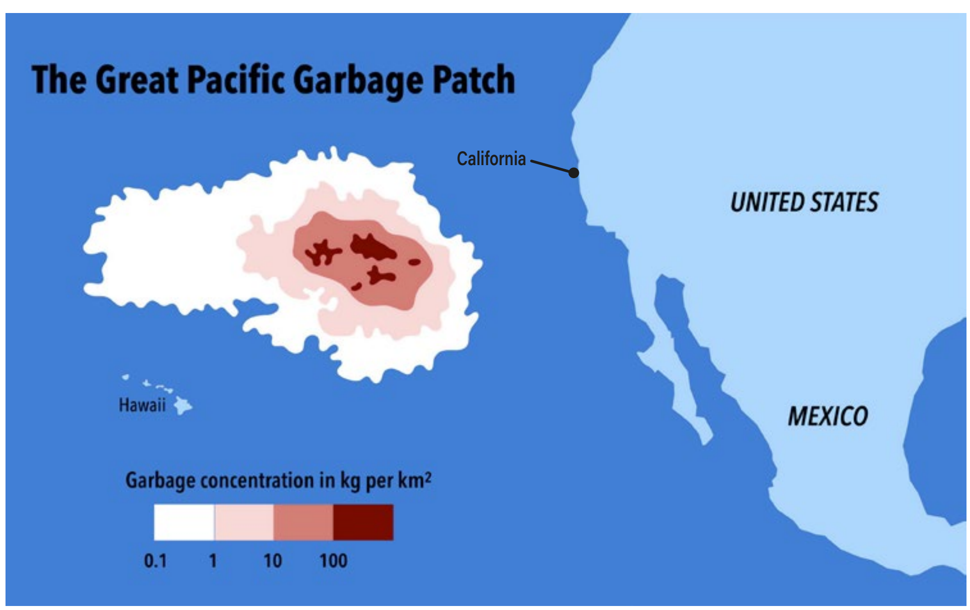
Demonstrate your understanding

3	4	5	
Explain the impact that exposure to the Sun has on ocean plastic.	Discuss the impact that shipping has on contributing to the Great Pacific Garbage Patch.	Analyse the impact that banning the use of plastic would have on the Great Pacific Garbage Patch.	
Assuming there was no reduction in the amount of plastic pollution moving into the oceans, predict how the size of the oceanic garbage patches would change over time.	Assess the reliability and validity of data from satellite imagery for estimating the size of an oceanic garbage patch.	Evaluate the following statement: 'Cleaning up oceanic plastic pollution is as simple as skimming leaves off the top of a swimming pool.'	Science how-to p. 420
Select one of your solutions and describe it in more detail. Include the following in your description: **a** how the plastic is collected and removed from the ocean. **b** what happens to the plastic that is collected.	Assess the effectiveness of your chosen solution for cleaning up: **a** plastics floating on the surface. **b** plastics in the water column. **c** microplastics. **d** macroplastics..	Evaluate the impact on plastic pollution in the oceans of cleaning up the Great Pacific Garbage Patch, compared to removing plastic pollution from rivers and near to shore.	Science how-to p. 425

Most plastic is not biodegradable. However, with exposure to sunlight, water and wave action, plastic items begin to break down into smaller and smaller pieces, eventually forming microplastics. Oceanic garbage patches are therefore mostly made up of microplastics floating in the water column, interspersed with larger objects such as discarded fishing nets and plastic crates floating on the surface.

The presence of plastic pollution in such large concentrations impacts the marine food web. Sea creatures and birds can become entangled in large pieces of plastic or mistake plastics for food. The presence of plastic on the surface, or lower down in the water column, can block sunlight, preventing phytoplankton from photosynthesising. It is also assumed that there are large amounts of plastic on the ocean floor beneath the garbage patches.

Figure 4.51: The Great Pacific Garbage Patch is the world's largest oceanic garbage patch, covering an area almost twice the size of New South Wales. Due to the movement of the ocean currents, there are areas that have higher concentrations of plastic than others.



Focus area 5

5.0 Genetics and evolutionary change

In the world around us, there is a massive range of living things. Plants, animals, microorganisms and more – the diversity of life on Earth is incredible. But how did this occur? Life on Earth has changed and diversified over time, becoming more complex and evolving into different species as environmental conditions have changed. The reason for these changes stems from the genetics of organisms. Offspring have been inheriting and passing on characteristics that are favourable for their survival for millions of years!

Learning Ladder

The Learning Ladder contains the scientific content and processes you will learn in this focus area. Each area has five levels of progression. To move to higher levels, you need to practise activities at the earlier levels. This will help you develop the ability to complete tasks that are more complex.

Steps in progression	Content: Genetics and evolutionary change	Working scientifically processes: Processing data and information	Working scientifically processes: Communicating	Steps in progression
5	I can evaluate evidence of how the diversity of life has changed over time.	I can evaluate investigations based on the quality of processed data.	I can evaluate scientific findings based on secondary evidence and arguments.	5
4	I can discuss how a range of organism characteristics provide evidence of genetic inheritance patterns and change.	I can use data to support or refute questions, hypotheses or solutions to problems.	I can present scientific findings using appropriate conventions for specific audiences.	4
3	I can explain how genetics can be examined and manipulated using different technologies.	I can process and interpret quantitative and qualitative data from a range of sources.	I can construct a range of appropriate scientific presentations based on first-hand and second-hand data and information.	3
2	I can describe how characteristics of organisms have been inherited, and changed, over time.	I can organise and represent data in appropriate ways, including in tables and graphs.	I can use digital technologies to organise and present data and information.	2
1	I can identify a range of characteristics relating to the genetics and evolution of organisms.	I can select and extract information from various texts and sources.	I can select appropriate ways to communicate information.	1

Figure 5.1: Before life on land appeared, marine organisms lived in Earth's oceans. Coral reefs, like the one shown here, contain thousands of organisms, from large to microscopic, that have evolved over generations to suit specific tropical environments.

5·1 ▸ Arrangement of genetic information

Learning intention

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

- identify that all organisms contain a genetic code
- compare DNA, chromosomes and genes, in relation to their roles in genetics.

Key terms

chromosome: a tightly coiled strand of DNA

deoxyribonucleic acid (DNA): the carrier of genetic information; located in the nucleus of a cell

double helix: the structure of a DNA molecule; a double-stranded spiral

gene: a segment of DNA, the basic functional unit of heredity

genome: an organism's entire sequence of DNA

genotype: the genetic code for an organism

heredity: the passing on of traits from parents to their offspring

nucleotide: the building block of DNA, consisting of a sugar, a phosphate and a nitrogenous base (adenine, guanine, thymine or cytosine)

phenotype: how the genotype is physically expressed

plasmid: a small circular DNA molecule in bacteria and some other microscopic organisms

Investigation 5.1

Extracting DNA from strawberries, page 529

Content group: DNA structure and function

Your genome is a blueprint unique to you. It contains all the instructions for your genetic traits, passed down from your mother and father. This blueprint is arranged in three distinct levels: genes, which are sections of DNA, which is stored as chromosomes.

DNA is made up of nucleotides

Our **deoxyribonucleic acid (DNA)** contains all our biological instructions. Located in the nucleus of nearly every cell, DNA is in the shape of a twisted ladder called a **double helix**. The sides of the 'ladder' are the backbone of DNA and are made up of units called **nucleotides**. Each nucleotide consists of a phosphate group, a five-carbon sugar and a nitrogen-containing base. In DNA, there are four nitrogenous bases – adenine, thymine, guanine and cytosine. They form pairs to make the 'rungs' of the ladder. The bases only partner in specific pairs: adenine with thymine, and guanine with cytosine.

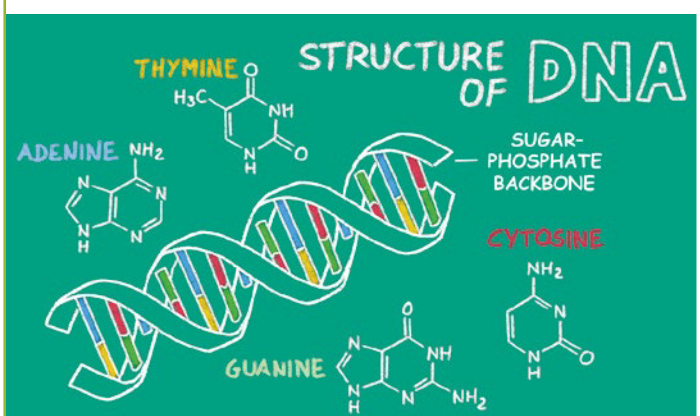


Figure 5.2: DNA is made up of nucleotide bases. Collections of these make up genes that code for proteins.

Genes are segments of DNA

One section of DNA is called a **gene**. A gene is the basic functional unit of **heredity**. Genes are how traits are passed down from a mother and a father to their offspring. Every human has two copies of each gene – one from their mother and one from their father.

Some genes code for proteins, which are the basic building blocks for our bodies. They:

- are used to repair and make new tissue
- make up much of our skin, hair, muscle and bone
- make up the chemical messenger system of hormones, blood and antibodies.

Other genes code for a variety of molecules with different functions. Some genes are common (such as those for brown eyes) and some are rarer (such as those for red hair).

Genes can vary in size – from a few hundred base pairs to millions of base pairs in length. Your genes make up your **genotype** – the genetic code for a specific gene or genes – and determine your unique genetic identity (your **genome**). The way the genes are expressed is known as your **phenotype**, which can be visible traits such as height, hair colour or eye colour, or characteristics such as blood type.

Condensed chromosomes contain tightly coiled DNA

In cells, DNA often exists as disorganised long pieces. Under a microscope, DNA can look like a bunch of squiggles. At various stages (especially during cell division), it becomes tightly coiled and packed. This packaged DNA is known as a **chromosome**.

Humans normally have 23 pairs of chromosomes (46 in total). Each chromosome is made up of two identical chromatids. The two chromatids are joined so that they have short and long arms. Each chromatid is made up of one long DNA molecule that has been tightly coiled and packed into the small structure. To ensure the DNA is effectively coiled and packed, it is wrapped around small protein balls called histones.

All organisms have a genetic code

All living things, whatever their size and shape, have a genetic code, containing specific genes that code for particular traits. These genes are linked as sections of DNA, which are stored in chromosomes.

In complex eukaryotic organisms, such as humans, condensed chromosomes typically form an 'X' shape, whereas in simple prokaryotic organisms, the chromosomes are circular and are called **plasmids**.

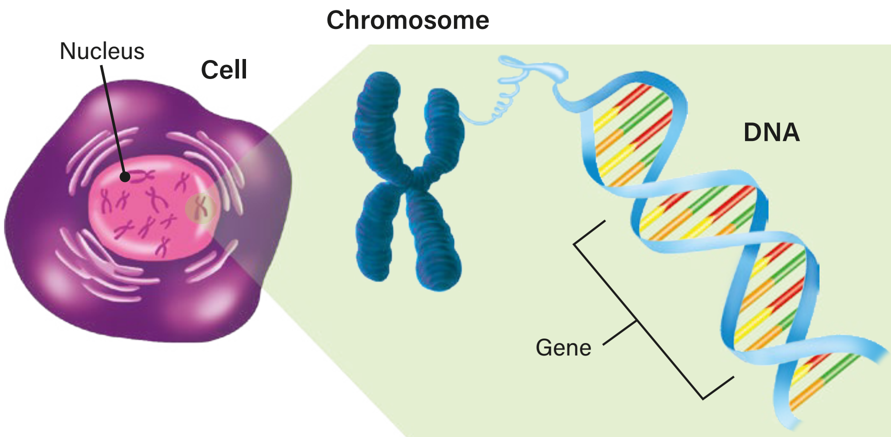


Figure 5.3: Cells contain chromosomes (made up of DNA) that contain our genes. The totality of all our genes is known as our genome.

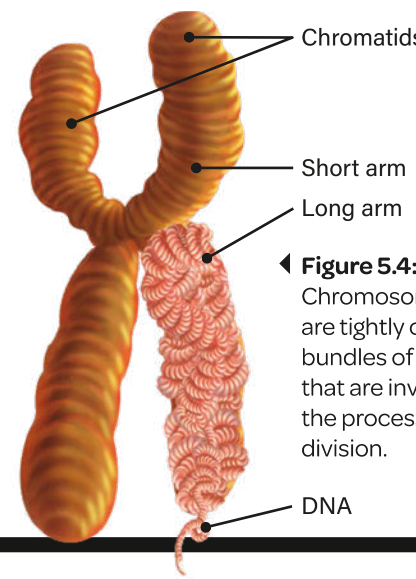


Figure 5.4: Chromosomes are tightly coiled bundles of DNA that are involved in the process of cell division.

Learning Ladder

Genetics and evolutionary change

1. Identify the main components in the structure of DNA.
2. Describe the relationship between DNA, chromosomes, genes and the genome.
3. Explain how the structure of genetic material is related to the traits expressed.

Communicating

see page 429

1. Describe how visual representations of genetic material help us to understand them.
2. Draw a digital diagram to demonstrate the relationship between DNA and the phenotype, including as many steps in between as possible.
3. Select one type of genetic material from this section and construct a labelled three-dimensional representation of it.

In context

All organisms contain genetic material. Propose reasons why the genetic material of simple and complex eukaryotic organisms is arranged in different ways.

Success criteria

- I can define the terms 'DNA', 'chromosome' and 'gene'.
- I can compare DNA, chromosomes and genes in relation to their roles in genetics.

5·2 ▸ The structure and function of DNA

Learning intention

At the end of this lesson, I will be able to explain how the structure of DNA is related to the functions it performs.

Key terms

amino acid: an organic molecule that is the building block of a protein

enzyme: a protein that increases the rate of a specific chemical reaction in the body

nitrogenous: containing nitrogen

proteins: long polymer chains made up of amino acid monomers

ribonucleic acid (RNA): a nucleic acid similar to DNA that helps to produce proteins from the genes of DNA

transcription: the process in which a cell makes an RNA copy of a piece of DNA

Content group: DNA structure and function

Long strands of DNA are arranged very specifically, which is important for how we function, repair ourselves when we get injured, and grow.

DNA is arranged as a double helix

The double helix of DNA is composed of two strands of DNA, each with a sugar–phosphate backbone. **Nitrogenous** bases in the nucleotides on one strand align with their complementary bases on the other strand and join together: adenine with thymine, and cytosine with guanine. A nucleotide consists of a sugar molecule, a phosphate molecule and a single nitrogenous base. In this way, the order of nucleotides on the DNA strands forms specific genes, which code for many different proteins.

Another important molecule is **ribonucleic acid (RNA)**. RNA is very similar to DNA – it also contains nitrogenous bases – but RNA exists as single strands, not double ones. Also, instead of thymine, RNA contains a similar nitrogenous base called uracil. RNA helps DNA to replicate and to use the genetic information in DNA to produce **proteins**.

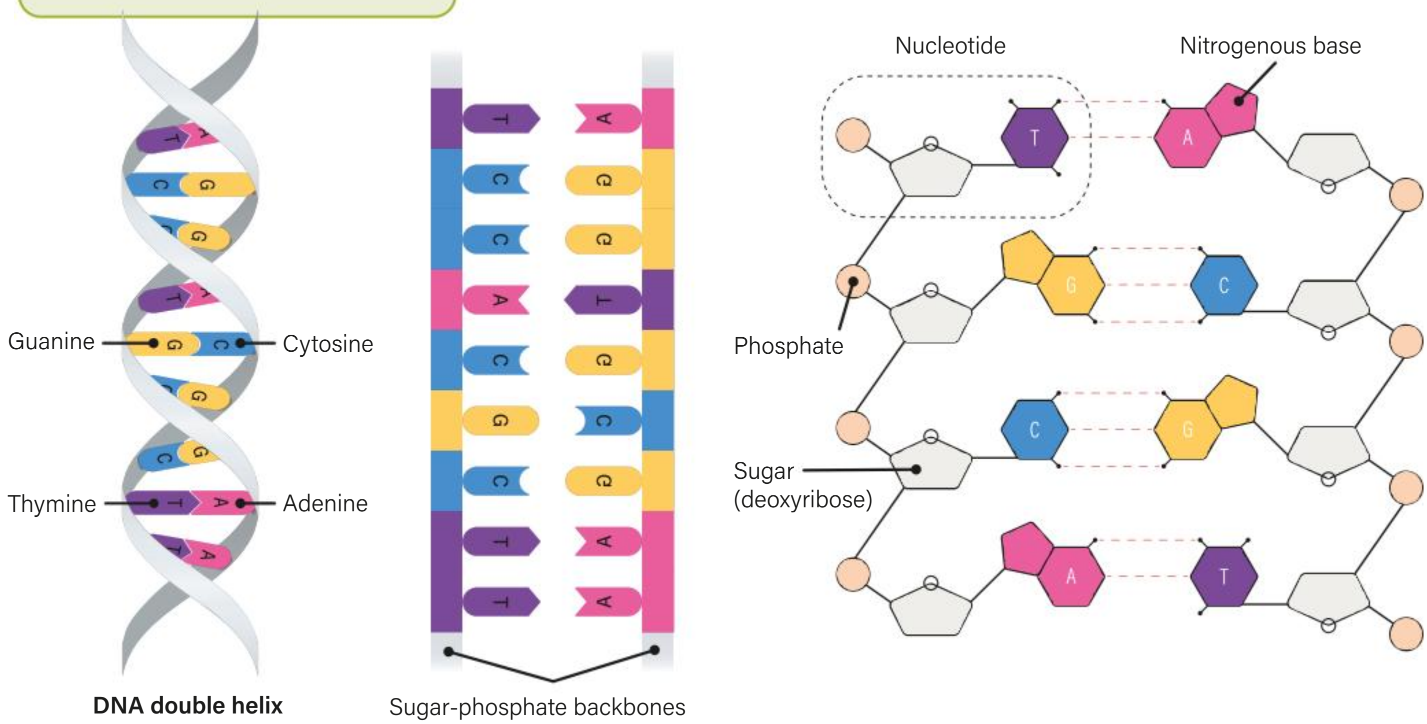


Figure 5.5: DNA is a double helix, which is composed of two complementary strands that join together to form a 'ladder'.

DNA is held together by chemical bonds

The DNA double helix is held together by different types of chemical bonds. The sugar–phosphate backbone and nucleotides are chemically bonded by covalent bonds, which are strong enough to hold together the nucleotides during replication and protein synthesis. However, the bonds between the nitrogenous bases in the middle of the ladder are weaker hydrogen bonds. This allows the double helix to be opened, so that its genetic codes can be read during protein synthesis.

Replicating DNA forms complementary strands

DNA is replicated so that new cells can form. The following steps occur (Figure 5.6):

1. The chromosome containing the DNA 'unwinds', so that the DNA is in long strands.
2. A section of DNA is 'unzipped' by an enzyme called DNA helicase, so that the nucleotides on both sides are available.
3. New nucleotides are matched to the existing ones on both sides of the DNA, by another enzyme called DNA polymerase.
4. Each of the new strands is 'glued' back together, making two identical double helixes from the existing one. These are called 'daughter molecules'.

The two new strands of DNA eventually condense into chromosomes. When the cell divides, each of the two new cells receives an identical copy of the replicated DNA. This means that our genetic code is passed on to all new cells.

Genes on DNA are used to produce proteins

When cells are not preparing to replicate, DNA has another role – protein production. This is done through two processes: transcription and translation.

During **transcription**, a section of the DNA strand that contains a specific gene unwinds. (This is different from replication, in which the whole length of the DNA strand unwinds.) Genes are specific sequences of nitrogenous bases.

A special type of RNA called messenger RNA (mRNA) reads the unwound section of nucleotides like a barcode and copies the nitrogenous bases that make up the gene. This is called a complementary strand, because, as each base is read, the RNA adds the opposite, matching the base to its chain. The bases are summarised in Table 5.1.

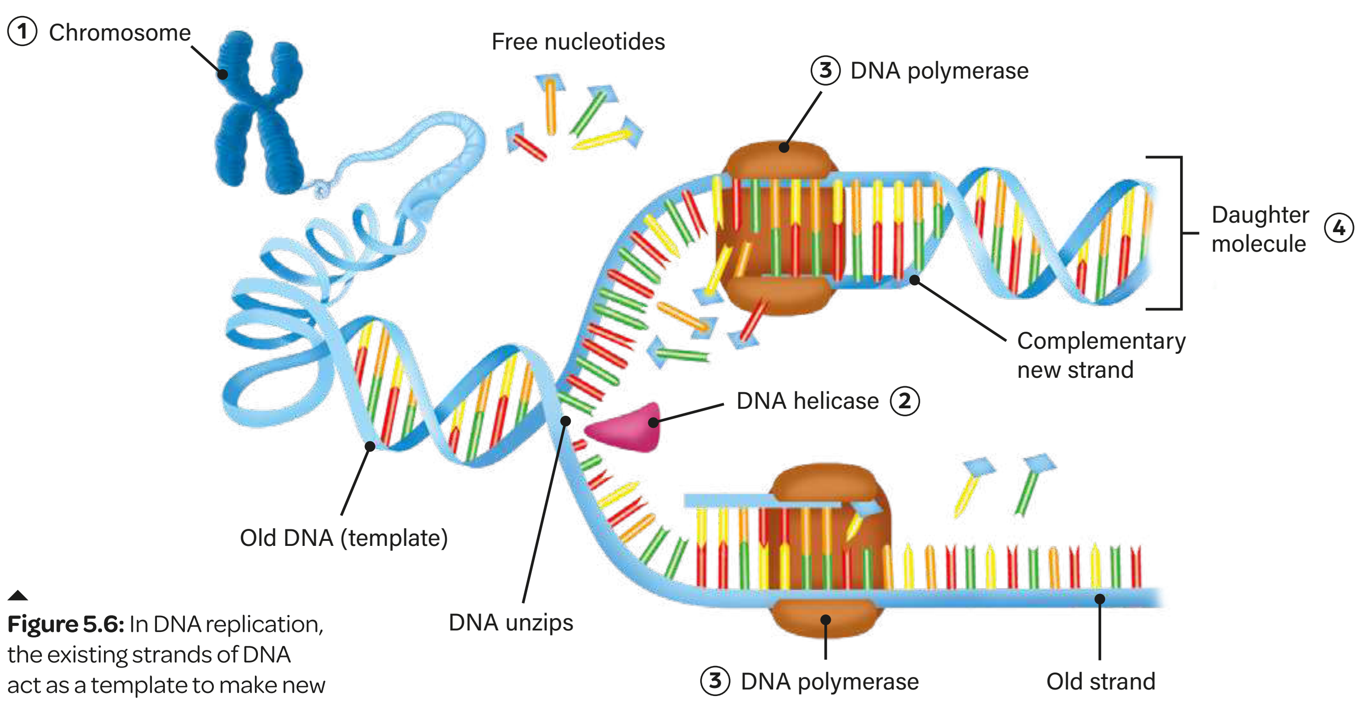


Figure 5.6: In DNA replication, the existing strands of DNA act as a template to make new complementary ones.

Table 5.1: Complementary DNA and RNA bases

DNA base		RNA base
Adenine (A)		Uracil (U)
Thymine (T)	pairs with	Adenine (A)
Cytosine (C)		Guanine (G)
Guanine (G)		Cytosine (C)

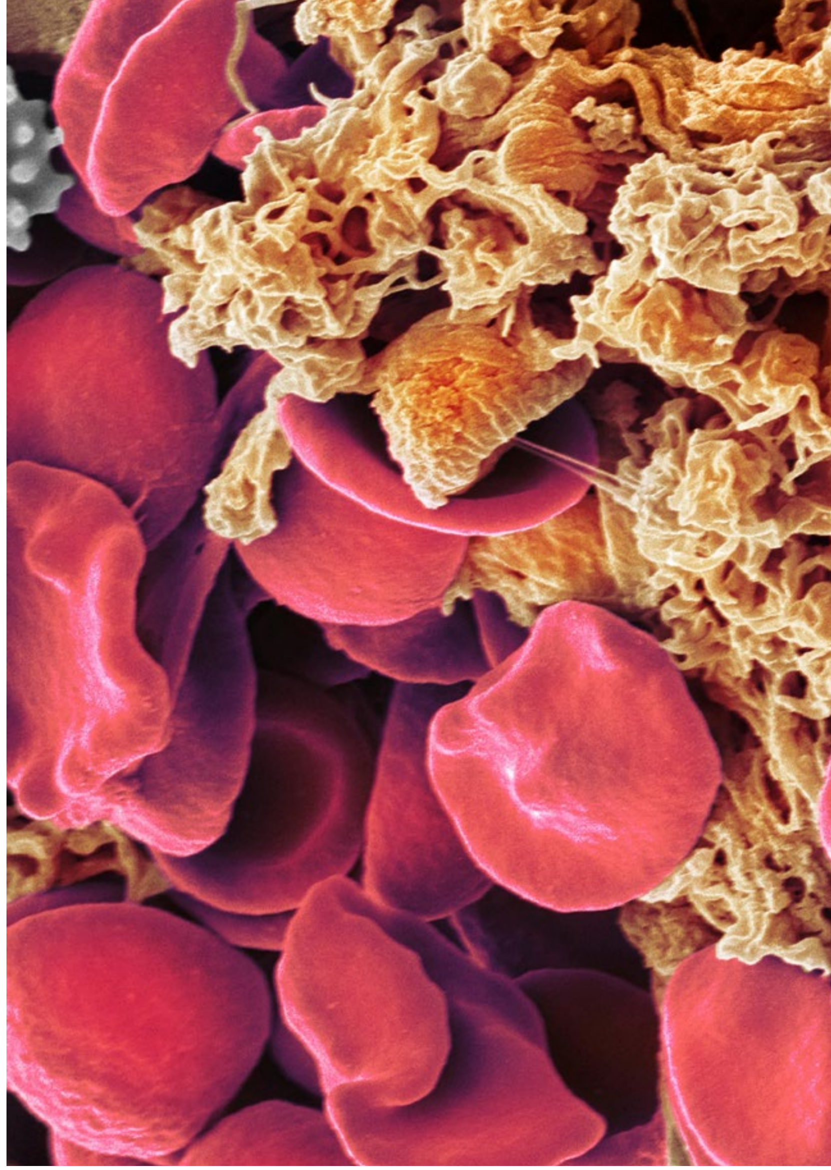
The strand of mRNA then heads to the ribosome, the cell organelle responsible for protein production. Here, the new code is read like a barcode a second time, translating it from nitrogenous bases into a chain of molecules called **amino acids**. These bond together, forming one long chain – a polymer. This step is called translation. The chain is then folded, using complex processes, becoming the final protein we need in our bodies. The longest protein in our bodies is a polymer made up of 34 000 different molecules.

Proteins have many functions

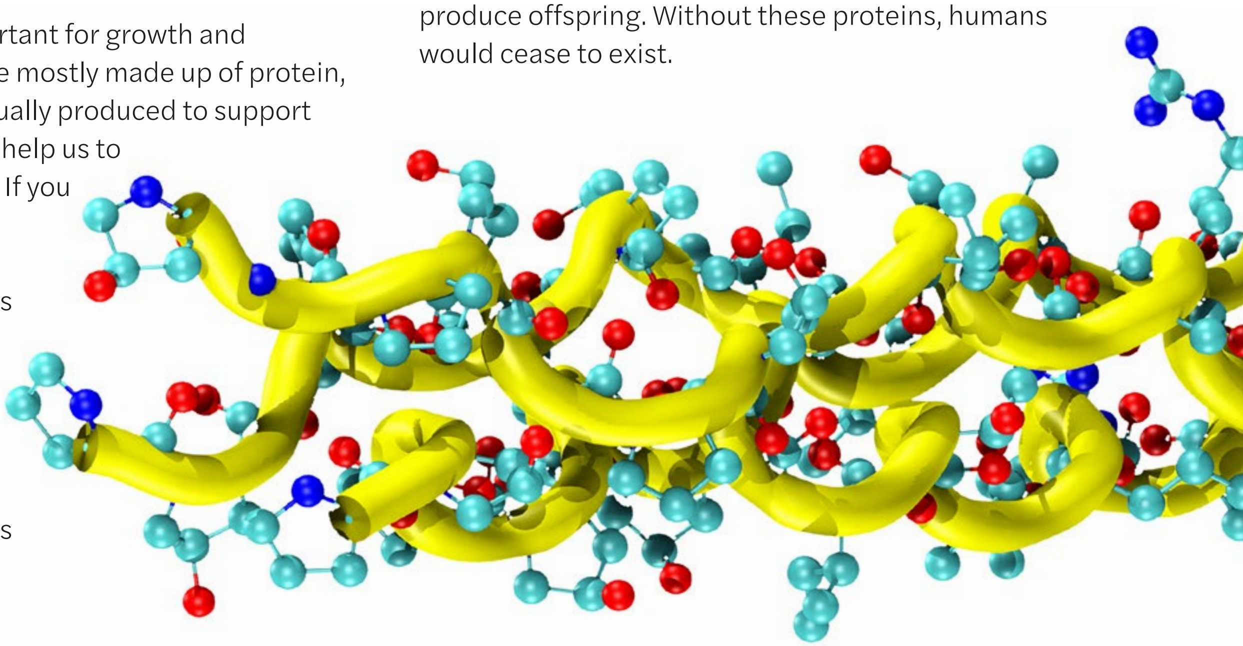
Proteins have many important functions in the body. Many cellular processes rely on specific proteins. These proteins are often in the form of enzymes and assist processes by speeding up important chemical reactions.

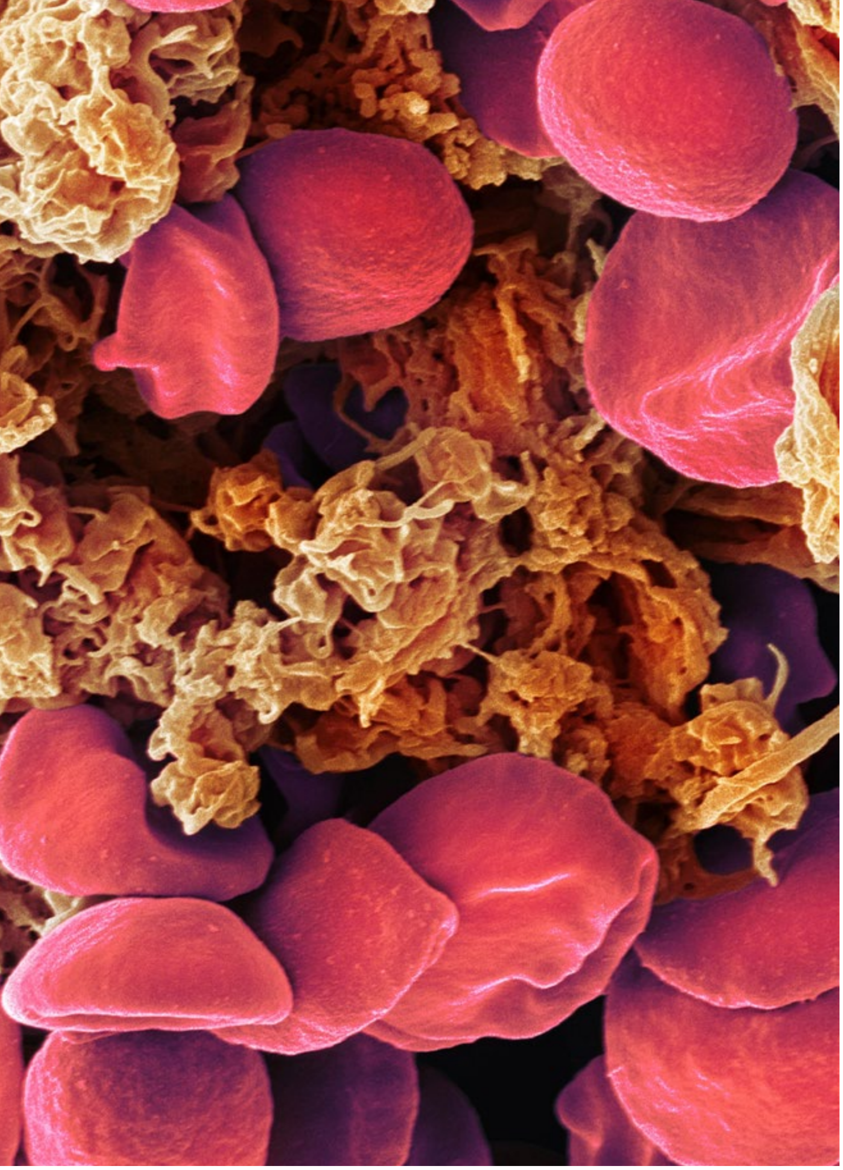
Examples of enzymes are amylase, which helps break down starches when we eat food, and lactase, which breaks down lactose (a sugar in milk), in our stomachs. Only some people have the gene for lactase. People who have it can drink milk without any ill effects, but those who lack the gene are lactose intolerant – and milk makes them sick!

Proteins are also important for growth and development. Muscles are mostly made up of protein, which needs to be continually produced to support growth. Proteins can also help us to heal when we are injured. If you cut yourself, the bleeding is stopped by specific blood cells called platelets (Figure 5.8). Platelets contain special proteins that allow them to stick to the edges of wounds, and to one another, forming clots and allowing us to heal.



Another important role of proteins is in reproduction. Proteins allow humans to produce hormones such as oestrogen and progesterone, which are essential during pregnancy to enable us to produce offspring. Without these proteins, humans would cease to exist.





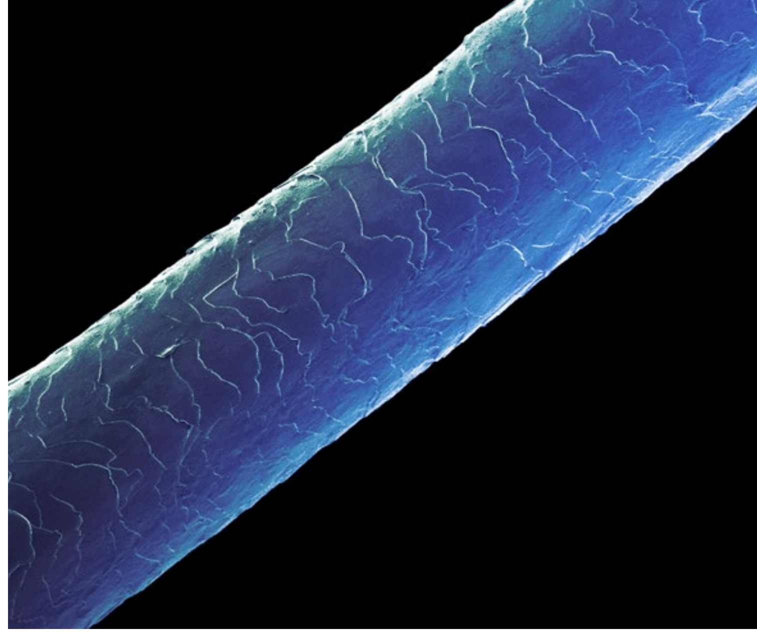
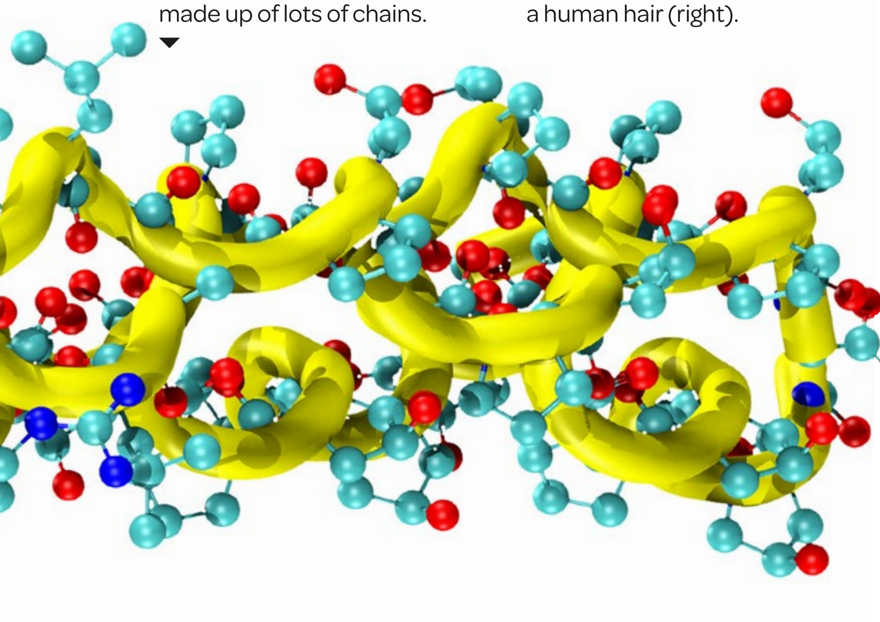


Figure 5.8: Proteins are important for many processes in the body. Platelets (left) allow blood to clot, while keratin makes up fingernails and hair, as seen on the micrograph of a human hair (right).

Figure 5.7: Proteins are polymers, meaning they are made of up of many units. The 3D structure shown here is a representation of collagen – a complex protein polymer made up of lots of chains.



Learning Ladder

Genetics and evolutionary change

1. Identify three features of a DNA strand.
2. Describe how the parts of a DNA strand are arranged.
3. Explain the relationship between the structure of DNA and the production of proteins.
4. Suggest three reasons why humans require many different proteins in their bodies.

Processing data and information *see page 412*

1. Complete the following sentences based on the information in the section:
   a Adenine (A) pairs with ______ .
   b Guanine (G) pairs with ______ .
2. Use the information from Figure 5.6, and the steps of DNA replication, to describe the roles of DNA polymerase and DNA helicase.
3. Consider the platelets in Figure 5.8. Describe how their structure would help them with allowing blood to clot.

In context

Our bodies require hundreds of thousands of proteins to function effectively. Using information from secondary sources, identify three common proteins in our bodies, and explain the roles they carry out that help us to function.

Success criteria

- I can explain the structure of DNA.
- I can relate the structure of DNA to the processes of replication and protein production.

5·3 ▸ Discovering the structure of DNA

Learning intention

At the end of this lesson, I will be able to discuss the roles of the scientists involved in the discovery of the structure of DNA.

Key term

nuclein: a name given to DNA when it was first discovered

Investigation 5.3

DNA lolly model, page 531

Content group: DNA structure and function

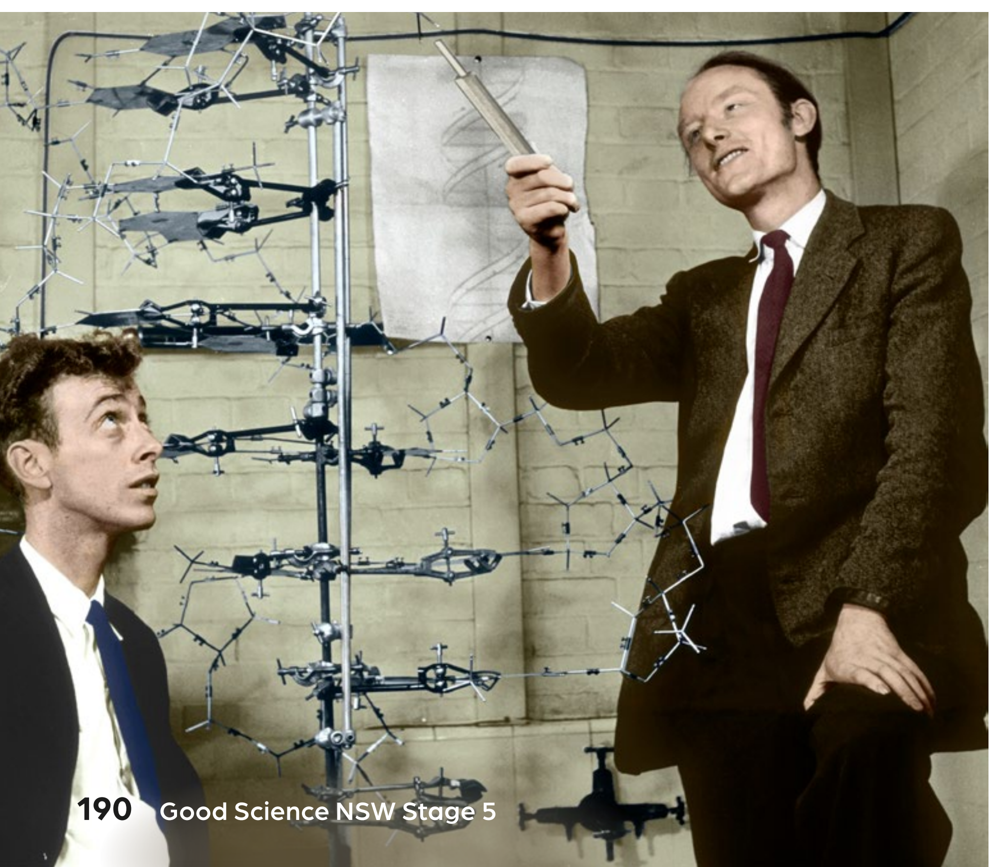
Although DNA was discovered in the 1860s, its structure was not known until much later. Two scientists – American biologist James Watson and British physicist Francis Crick – presented their model of the DNA double helix in the 1950s. However, their model was based not only on their work but also on the work of other scientists, some of whom remained largely uncredited.

DNA was discovered and investigated across many decades

In 1869, Swiss chemist Friedrich Miescher first found evidence of DNA in cells while investigating white blood cells. He called the molecule **nuclein**, but over time its name changed to deoxyribonucleic acid (DNA) as more discoveries were made.

The next scientists to contribute to our understanding of DNA were Russian biochemist Phoebus Levene and Austrian biochemist Erwin Chargaff. In 1919, Levene proposed that nucleic acids were composed of a series of nucleotides, and that a nucleotide was made up of one of four nitrogenous bases, a phosphate and a sugar molecule, which were always linked in the same order. New evidence quickly modified this idea when Chargaff showed that the order in which nucleotides are linked is highly varied. Chargaff concluded that in every species, the amounts of adenine and thymine were similar, as were the amounts of cytosine and guanine.

Figure 5.9: James Watson and Francis Crick with their famous model of DNA ▾



The Watson–Crick model shows DNA as a double helix

The Watson–Crick model of DNA is the model currently accepted and used around the world. The model is a double-stranded twisted helix (Figure 5.10). The two strands of DNA are antiparallel (parallel, but in the opposite direction) to each other and have a sugar–phosphate backbone. The four nitrogenous bases (adenine, thymine, cytosine and guanine) connect the two backbones and exist in pairs held together by hydrogen bonds between the nitrogenous bases.

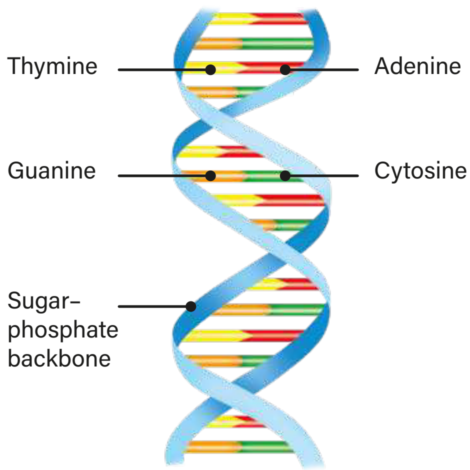


Figure 5.10: The 1953 Watson–Crick model of DNA is still used around the world today.

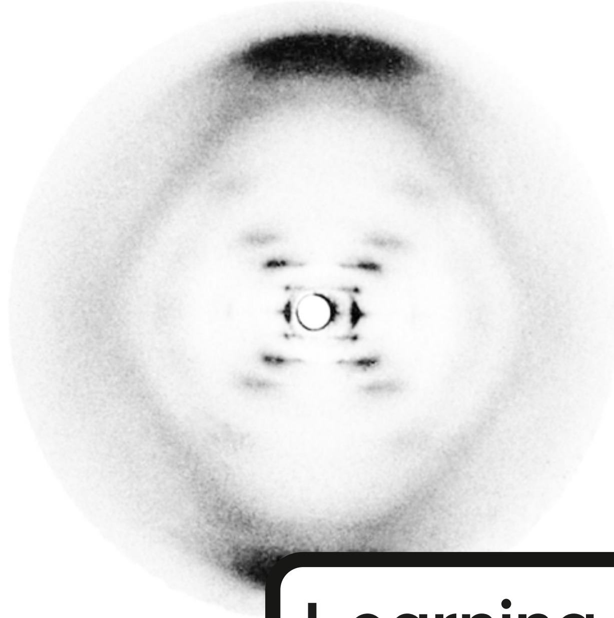


Figure 5.11: 'Photograph 51.' This photo was taken by Rosalind Franklin by using X-rays, which provided supporting evidence for the Watson–Crick model of DNA.

DNA sequences are written out using letters to represent the bases: A, T, C and G. Watson and Crick presented their model of DNA in 1953.

Franklin and Wilkins played a key role in the Watson–Crick DNA model

Although Watson and Crick were widely credited for their model of DNA, two other scientists also played roles in the discovery. Maurice Wilkins was a New Zealand physicist who worked with English chemist Rosalind Franklin. Wilkins proposed the idea of using X-rays to photograph DNA to observe its structure. Franklin was able to do so, eventually obtaining 'photograph 51' (Figure 5.9), which supported the idea of the double helix structure. Wilkins showed 'photograph 51' to Watson and Crick, who used it as evidence in their published paper without giving Franklin credit for it.

Watson, Crick and Wilkins shared a Nobel Prize

In 1962, Watson, Crick and Wilkins received a joint Nobel Prize in Physiology or Medicine for their discovery of the molecular structure of DNA. Although Franklin's work was key, she did not receive the Nobel Prize because she had died four years previously and Nobel Prizes are not awarded posthumously (after death). Also, a Nobel Prize can only be shared by up to three people.

Learning Ladder

Genetics and evolutionary change

1. Identify the four scientists involved in the discovery of the structure of DNA.
2. Describe the role Watson and Crick played in presenting the structure of DNA.
3. Explain how Franklin used technologies of the time to provide supporting evidence for the double helix structure of DNA.
4. Discuss the factors that led Chargaff to make different conclusions about DNA than the conclusions Levene had drawn.

Communicating

see page 429

1. Propose two appropriate ways to present information on the structure and function of DNA.
2. Construct a digital timeline that shows the roles of the scientists discussed in this section, and their contributions to our understanding of DNA.
3. Construct a labelled model of DNA that you could present to a Year 8 student that would enable them to understand its structure.
4. Write a brief speech that explains your model and that you could deliver to students viewing it.

In context

Our understanding of structures like DNA is continually improving. Research and explain a technology that is used today that assists scientists in their understanding of DNA as a molecule.

Success criteria

- I can identify the scientists involved in the discovery of the structure of DNA.
- I can discuss the contributions made by each scientist.

5·4 ▸ Cell division and reproduction

Learning intention

At the end of this lesson, I will be able to explain the processes of mitosis, meiosis and reproduction, and how they relate to inheritance.

Key terms

asexual reproduction: reproduction in which a single parent produces a genetically identical offspring

binary fission: cell division in single-celled organisms that produces offspring identical to the parent

cell cycle: the process a cell goes through every time it divides

clone: a gene or an organism that is genetically identical to its parent

crossing over: the exchange of genes by homologous chromosomes

diploid: has two sets of chromosomes

gamete: a sex cell – an ova or a sperm

haploid: has a single set of chromosomes

homologous: chromosomes that have the same genes in the same order

meiosis: complex cell division that produces unique haploid gamete cells

mitosis: simple cell division that produces identical cells

sexual reproduction: reproduction in which gametes from two parents fuse to produce a genetically unique offspring

Content group: Variation and inheritance

You started your life when an egg cell was fertilised by a sperm cell. The fertilised cell divided into two, then four, then eight, and so on, until you eventually became the approximately 32.7 trillion cells that you are today. None of this would have been possible without cell division. Cell division is important for organisms to grow, repair body tissues and reproduce.

Figure 5.12: Some plants can reproduce both sexually and asexually. Strawberry plants have flowers, so they can reproduce sexually, but they can also reproduce asexually by sending out runners along the ground, from which new, identical plants will grow.

Figure 5.13: The severed ▸ arm of this sea star is in the process of generating new arms, which will produce a new and identical sea star.

Mitosis produces identical cells

All our cells divide so that we can function as a living organism. For our body cells, this division occurs through the process of **mitosis**. Mitosis is one stage of the **cell cycle**, which occurs in every cell in our body apart from the sex cells. During the main part of this cycle, called interphase, the cell produces the substances needed and does its required job in the body. It also replicates all the DNA in its chromosomes (Figure 5.14).

Once the cell cycle reaches the stage of mitosis, the cell can divide. This happens in four steps:

1. **Prophase:** The chromosomes condense (coil up), and the nucleus breaks down. Special spindle fibres start to develop.
2. **Metaphase:** The chromosomes line up across the equator (middle) of the cell, and spindle fibres attach to either side of them.
3. **Anaphase:** The spindle fibres pull the chromosomes away from the centre towards either side of the cell, and the cell elongates (becomes longer).
4. **Telophase:** The chromosomes on each side of the cell are released from the spindle fibres and unwind, while a nucleus starts to re-form around them. The middle of the cell starts to pinch inwards.

After telophase, the cell splits in half, down the middle. This splitting of the cell is known as cytokinesis. Cytokinesis is the conclusion of cell division, as the one parent cell has now completely divided into two identical daughter cells.

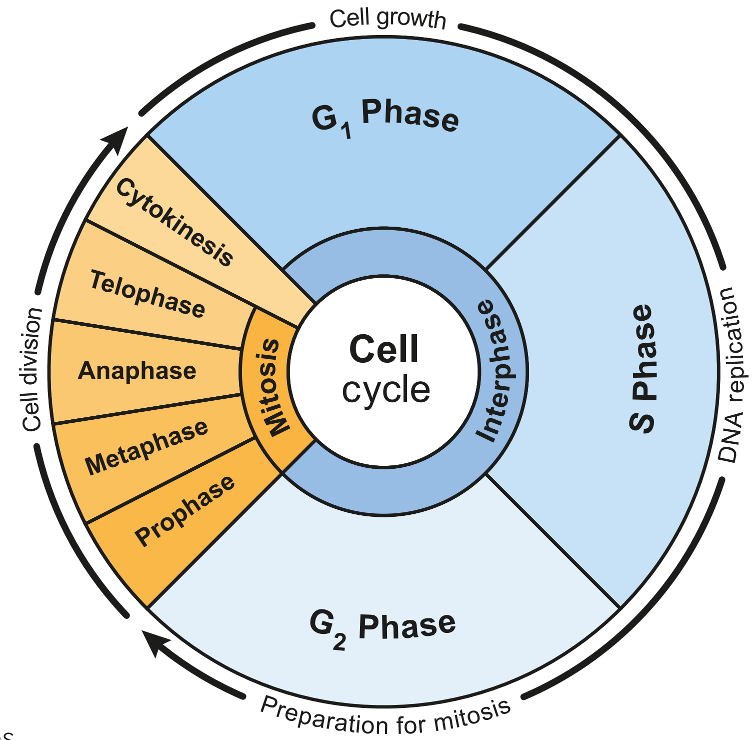


Figure 5.14: The cell cycle shows all the processes a normal body cell goes through, including mitosis.

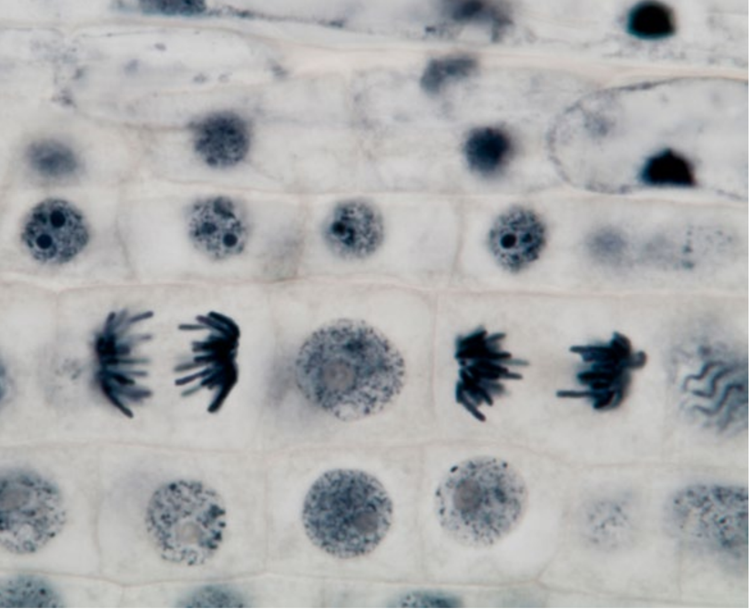
Growth and repair occur because of mitosis

The process of mitosis is very important because it allows for both growth and repair to occur. Growth happens when body tissues increase in size. This is not due to cells getting larger but to cells dividing to create more cells. As the number of cells in a tissue increases, the size of the tissue also increases, causing the organism to grow.

The growth of an organism is influenced by many factors, but the overall height and structure of an organism are determined by its genes. This is the reason humans do not grow as large as elephants.

Cells are constantly dividing to replace cells that are damaged or old. Cell division ensures that cells in the body are healthy and can perform the functions needed for survival. Some cells, such as those in the stomach and intestines, only last a few days because they are exposed to conditions that damage them. Others, such as liver cells, live much longer because they are less likely to be damaged.

Not all body cells can be replaced. For example, nerve and heart muscle cells are unable to divide, so any damage to these cells can be permanent.



▲ **Figure 5.15:** Cells undergo mitosis, as shown in this micrograph, so that organisms can grow and repair themselves.

Meiosis produces unique, haploid cells

Unlike other body cells, which divide once, sex cells (**gametes**) divide twice in a process called **meiosis**. This extra division produces sex cells that have half the usual number of chromosomes found in other cells of the body, making them **haploid** cells.

Meiosis also happens in stages, meiosis I and meiosis II, which look very similar to mitosis (Figure 5.16). After interphase, the DNA of the cell is replicated, ready for division. Then, meiosis starts.

Meiosis I

1. **Prophase I:** Chromosomes condense (coil up), and pairs of chromosomes that have the same genes in the same order (**homologous**) match up and randomly switch segments of their genetic material in a process known as **crossing over**. This mixes up the genes, making the chromosomes different from the original chromosomes. The nucleus breaks down, and spindle fibres appear.
2. **Metaphase I:** Pairs of chromosomes line up across the equator (middle) of the cell, and spindle fibres attach to them.
3. **Anaphase I:** Chromosome pairs separate to the opposite ends of the cell, and the cell elongates (gets longer).
4. **Telophase I:** The chromosomes are released from the spindle fibres, while a nucleus starts to form around each set. The middle of the cell starts to pinch inwards.

After telophase, cytokinesis occurs and the parent cell again splits into two identical daughter cells. However, unlike in mitosis, these cells are unique, and they immediately enter into another round of division: meiosis II.

Meiosis II

1. **Prophase II:** The nucleus of each daughter cell dissolves, and spindle fibres appear in both cells.
2. **Metaphase II:** The chromosomes line up across the equator (middle) of each cell, and spindle fibres attach to either side of them.
3. **Anaphase II:** Spindle fibres pull the chromosomes towards each side, and the cells elongate.
4. **Telophase II:** The chromosomes on each side of both cells are released from the spindle fibres and unwind, while a nucleus starts to form around them. The middles of the cells start to pinch inwards.

When round two of telophase is complete, cytokinesis occurs again, and the two cells are split in half into four unique daughter cells. Each cell is haploid, containing half the number of chromosomes of the original (**diploid**) parent cell, and contains a unique mixture of the genetic material from its chromosomes.

Cell division allows species to reproduce

For a species to continue, it needs to reproduce. Different species reproduce in different ways, which can result in offspring that are identical or unique. When reproduction produces new offspring, they have inherited genetic traits from one or more parents. The use of only mitosis (or mitosis-like) division results in identical offspring, while meiosis will form unique offspring.

Reproduction can be sexual or asexual

For all species, reproduction only ever happens in one of two ways: sexual or asexual reproduction.

Sexual reproduction requires two parent organisms – one male and one female. Each parent contributes a sex cell – an **ovum** or a **sperm**. The male sex cell fertilises the female sex cell, and the cell produced develops into a new, genetically unique offspring.

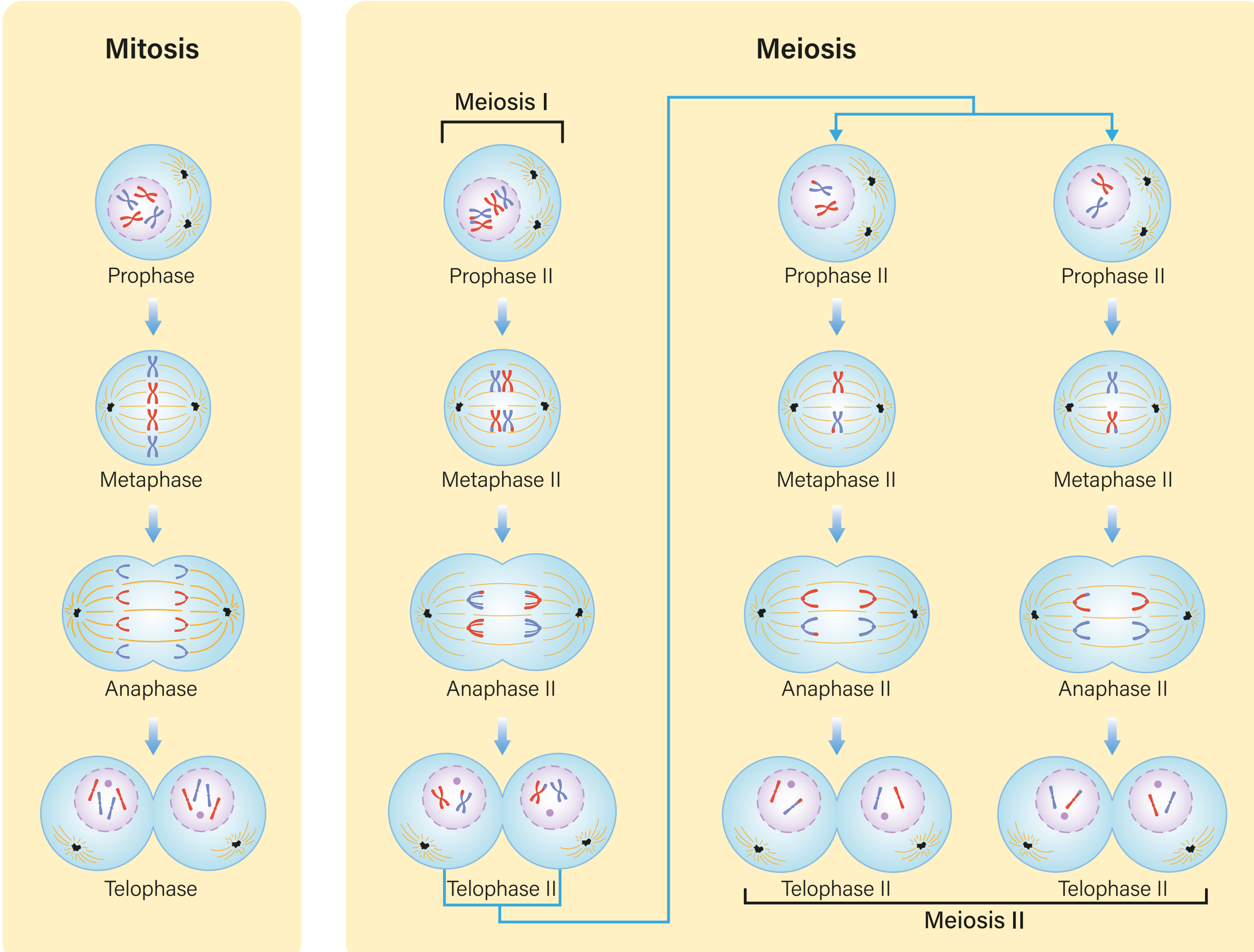


Figure 5.16: The processes of mitosis and meiosis each produce new cells; however, cells produced by mitosis are identical, whereas cells produced by meiosis are not identical.

Fertilisation can occur either internally (inside the female body) or externally (outside the female body), depending on the species.

In **asexual reproduction**, there is only one parent organism. This organism either divides in half completely, through a process similar to cell division, or part of it separates off and develops into a mature, genetically identical offspring. Offspring that are produced by asexual reproduction can be referred to as **clones**.

Some organisms rely solely on one type of reproduction, whereas others can use both methods. For example, some flowering plants produce identical copies of themselves by asexual reproduction, but also produce pollen in their flowers. If pollen reaches the flower of another plant, it may fuse with an ovum in the flower, producing a unique offspring of the plant. Table 5.2 summarises the types of reproduction in organisms.

Table 5.2: Different organisms and their methods of reproduction

Type of organism	Type of reproduction	Example organism
Animal	Both	Sexual – mammals (e.g. humans, zebras)
		Asexual – sea stars
Plant	Both	Sexual – roses
		Asexual – potatoes
Bacteria	Asexual	*Escherichia coli* – bacteria
Fungus	Both	Sexual – mushrooms
		Asexual – yeast
Protist	Asexual	Amoebas

Figure 5.17: Sometimes human twins are genetically identical, and sometimes they are not, even though both are produced from cells produced by meiosis! Can you think of a reason why this may be the case?

Single-celled organisms reproduce by binary fission

Simple prokaryotic organisms consist of just one cell. This cell carries out all the functions required for the organism to survive. These organisms do not need partners to reproduce or multiply – they just split in half, in a process called **binary fission**. Binary fission is a form of asexual reproduction.

Before a cell undergoes binary fission, the genetic material inside doubles in amount. The cell then splits in two, and each new cell includes half of the genetic information. Only very simple cells, such as bacteria, can reproduce by binary fission. As well as being simple, binary fission is fast: some bacteria can split in half every 20 minutes. Binary fission is very similar to the process of mitosis.

Table 5.3: The number of identical organisms produced each time bacteria reproduce by binary fission

Time passed (min)	0	20	40	60	80	100
Number of cells	1	2	4	8	16	32

Gametes produced by meiosis are involved in sexual reproduction

During sexual reproduction, a haploid male and a female gamete fuse to form a single diploid cell. This means that the number of chromosomes of the original parent cell is restored in the offspring. In humans, each gamete (sperm and ovum) has 23 chromosomes. The fertilised egg has 46 chromosomes, which is the normal number of chromosomes for a human. Meiosis ensures that offspring do not contain more chromosomes than they should.

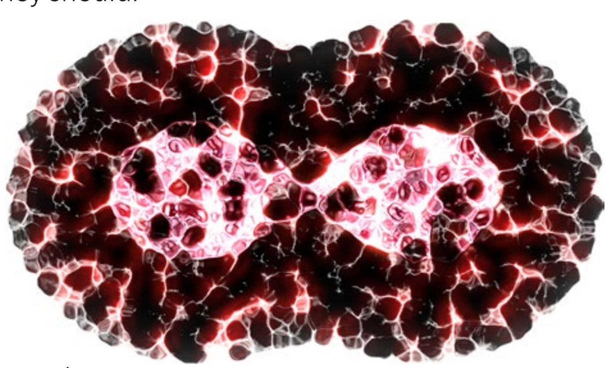


Figure 5.18: This image taken using a microscope shows onion cells during the process of mitosis.

Learning Ladder

Genetics and evolutionary change

1. Identify the cell division process that results in a:
   - **a** human egg cell.
   - **b** bacteria cell.
   - **c** liver cell.
2. Describe how meiosis allows us to inherit characteristics from our parents.
3. Explain the process of mitosis, and describe how it is used in the body.
4. Strawberry plants can reproduce by asexual runners. However, they also produce flowers, which can disperse pollen. Discuss the genetics of the offspring that may be produced by strawberry plants.

Processing data and information *see page 412*

1. Describe how the number of cells increases as time doubles.
2. Construct an appropriate graph to display the information from Table 5.3.
3. Using the graph and trend line constructed in Question 2:
   - **a** estimate the number of cells at 120 minutes.
   - **b** extrapolate the trend line to estimate the number of cells at 180 minutes.
4. A student proposed the following statement: 'If harmful bacteria enter the body and are not detected by the immune system, the body could be overrun in just 24 hours.' Consider the data you have available and use it to support or refute this statement.

In context

Organisms that reproduce sexually rely on either internal or external fertilisation. Use research from secondary sources to explain each process, outlining one benefit and one limitation of each. Identify two organisms that use each method of fertilisation.

Success criteria

- I can explain the processes of mitosis and meiosis.
- I can explain how organisms use mitosis and meiosis in their reproduction.

5·5 ▸ Human reproduction

Learning intention

At the end of this lesson, I will be able to identify the structures of the human reproductive system and outline their use in human reproduction.

Key terms

menstruation: monthly discharge of blood and tissue from the lining of the uterus

ovum: a female sex cell, also known as an egg cell (plural ova)

semen: protective fluid that contains sperm

sperm: a male sex cell

Content group: Variation and inheritance

Like all other organisms, humans need to reproduce. With more than 8 billion of us, there is a range of genetics that are passed from parents to offspring, all over the world, through reproduction.

Humans reproduce by sexual reproduction

The male and female human reproductive systems are nearly always active. Men produce about 1500 sperm every second, and women release an egg every month. Sperm must be able to survive while traversing the female reproductive system. Only one sperm will fertilise an egg to begin the process of producing a new organism.

In order for humans to reproduce, the sex cells need to be produced by meiosis, so that they contain unique genetic material and the correct number of chromosomes. Most of the cells in our body are diploid – and contain 46 chromosomes, arranged as 23 pairs. However, if human sperm and eggs were diploid, offspring would contain 92 chromosomes. For this reason, sex cells are produced by meiosis and divide twice, reducing their number of chromosomes to one single set of 23. This makes these cells haploid – they have half of the normal amount of genetic material. So, when a sperm and an egg cell unite, the resulting new organism will also contain 46 chromosomes, as 23 pairs.

The female reproductive system

The female reproductive organs are the vagina, uterus, fallopian tubes and ovaries (Figure 5.19). There are two ovaries, one on either side of the uterus. Ovaries are oval-shaped glands that produce the reproductive hormones oestrogen and progesterone. Ovaries also contain ova (eggs). These are the gametes (sex cells) of women and are also known as oocytes. Girls are born with all the eggs they will ever have, about 2 million.

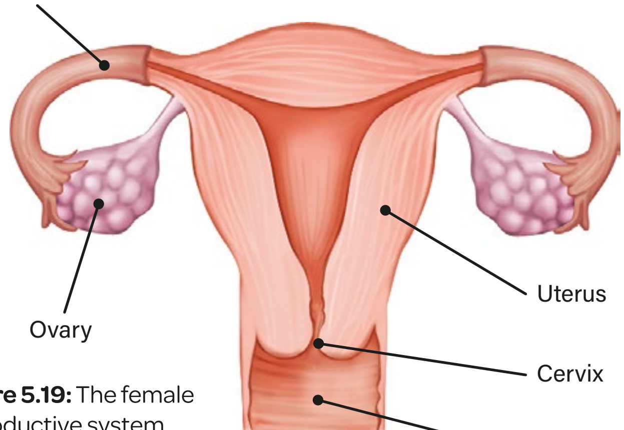


Figure 5.19: The female reproductive system

The menstrual cycle allows females to become pregnant

When a girl starts menstruating, an egg (or **ovum**) is released every month down her fallopian tubes (the left and right, alternately). The fallopian tubes act as transport tunnels for the eggs to travel from the ovaries to the uterus. If an ovum is fertilised by a sperm, it develops and embeds in the wall of the uterus, which acts as a 'nest' for the developing embryo. The uterus wall is lined with tissue, blood and blood clots. If no fertilised egg is present, this material is shed through the cervix and the vagina and is observed as **menstruation**.

The male reproductive system

The male reproductive organs are the penis, testicles, epididymis, vas deferens and prostate gland (Figure 5.20). The testicles are outside the body in a sac called the scrotum. The testicles are glands that produce sperm and the male sex hormone testosterone.

The gametes of men are called **sperm**. The sperm travel from the testis to the vas deferens through a tube called the epididymis. The vas deferens is a duct that then transports the sperm to the ejaculatory duct. The penis has a single opening called the urethra, and both sperm and urine can travel down this passage.

The prostate gland's function is to secrete the fluids that are expelled with sperm. These fluids and sperm together are referred to as **semen**. The semen provides a medium for sperm to swim through and lubricates the urethra. When aroused, the penis floods with blood, stretching and becoming erect. This blocks off access to urine so that only semen can travel down during ejaculation.

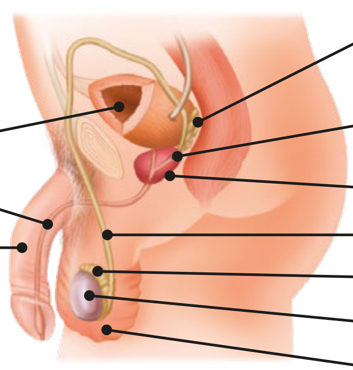


Figure 5.20: The male reproductive system

Ova are much bigger than sperm

Ova are the biggest human cell type (about 0.1 mm in diameter). They are visible to the naked eye and dwarf the tiny sperm cells (0.05 mm) (Figure 5.22). An ovum has a nucleus that contains the genetic material. Around the nucleus is a cell plasma (yolk). In the cell plasma are all the substances required for the ova to develop if it is fertilised by a sperm cell.

Sperm cells have a head that contains a nucleus with the genetic material inside. Sperm also have a long tail (or flagellum), which propels the sperm forward by a wave-like motion and is used to dig into and penetrate the female ovum (Figure 5.21).

Figure 5.21: The sperm penetrates an ovum (egg) to produce a new cell.

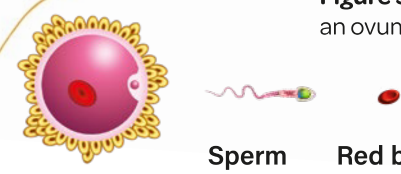


Figure 5.22: The female sex cell, the ovum, is one of the largest cells in the body.

Learning Ladder

Genetics and evolutionary change

1. Identify the type of reproduction used in humans.
2. Describe the path of an egg cell that is fertilised by a sperm.
3. Explain how human reproduction results in offspring that contain genetic material from two parents.
4. Discuss the significance of the production of semen by the male reproductive system.

Communicating

see page 429

1. Describe a way that you could communicate information that compares the size of human body cells, including reproductive cells.
2. Construct your described method of communication digitally.
3. **a** Consider the information provided on the female reproductive system and describe how you could visually represent this information.
   b Construct your representation so that it could be presented to another student in your class.

In context

When a fertilised egg implants in the uterus, it develops until a baby is born. Use secondary research to outline the main steps of development, from egg to baby, that occur during human pregnancy.

Success criteria

- I can outline the process of human reproduction and describe why it is important.

5·6 ► Genes and the environment

Learning intention

At the end of this lesson, I will be able to identify how genes and the environment interact when organisms are developing traits.

Key terms

allele: a variation of a gene

environmental factor: something in the environment that affects gene expression

expression: the process of converting the instructions in DNA into a trait, such as a protein

monogenic: influenced by a single gene

polygenic: influenced by two or more genes

Investigation 5.6

Genetic trait survey, page 532

Content group: Variation and inheritance

Every physical feature we have is because of the genes in our DNA. Our hair, eyes, teeth, fingernails and skin colour are all related to our genes. But is that all that controls these traits?

Genes can be varied

Scientists estimate that in the human genome, there are more than 20 000 genes that can be used to produce proteins. Some of those genes are **alleles**, which are variations of the same gene that can cause slightly different proteins to be produced. These variations occur because the sequence of nucleotides that make up the gene is slightly altered. The alleles you inherit from your parents will influence all your traits.

Almost every gene in your body is one of a pair, which work together to express traits. This combination of two alleles (genes) that influence the same trait is called the genotype.

Some traits are influenced by many genes

Some traits, such as dimples and the ability to roll your tongue, are controlled by a single gene. They are **monogenic**. Other traits, such as height and skin colour, are more commonly **polygenic** – they are influenced by several genes. The way these traits are expressed is called the phenotype, which is what we physically see. Your genotype, which is inherited from your parents, determines your phenotype.

Some traits are controlled by multiple alleles; other traits are controlled by just one pair of alleles. These alleles determine the phenotype of an organism – what is physically expressed; for example, dimples, widow's peaks and freckles in humans, and flower colour in plants.

Table 5.4: Environmental influences on some traits

Organism	Trait	Environmental factor
Hydrangea	Flower colour	Soil pH level
Siamese cat	Fur colour: dark patches around nose, ears, paws and tail	Temperature
Turtle	Sex	Temperature
Banksia	Leaf size	Sunlight exposure

Genes are influenced by environmental factors

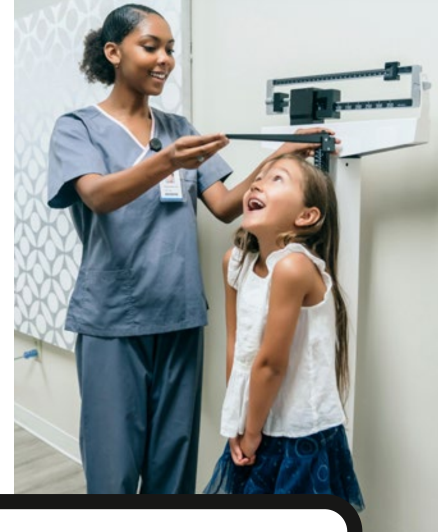
Gene **expression** is influenced by external **environmental factors**.

For example, skin colour is influenced by your genes, but also by sunlight. Your skin will tan or get darker the more sunlight (ultraviolet rays) you are exposed to. Height can also be influenced by environmental factors. A diet low in vital nutrients can restrict a child's growth. This can result in shorter individuals or in diseases such as rickets, which causes the bones of the leg to bow.

The genes of all organisms are affected by the environment. Table 5.4 summarises some traits of other organisms that are influenced by their environment.

Figure 5.23: The darker patches of fur on a Siamese cat are due to the interaction between proteins produced from their genes and cooler temperatures.

Figure 5.24: Our height is determined by our genes but can also be influenced by environmental factors such as our diet.



Genes can provide clues about our ancestry

Skin colour is related to how much of the pigment melanin is present; the more melanin you produce, the darker your skin is. In the past, populations that lived close to the equator were exposed to higher levels of sunlight than those who lived closer to the North or South Pole. This meant that they needed higher levels of melanin to protect themselves from harmful ultraviolet rays, which could cause damage and skin cancer. So, if you have more melanin today, chances are your ancestors grew up somewhere with lots of sunlight.

Figure 5.25: The colour of hydrangea flowers is influenced by the pH level in the surrounding soil.

Learning Ladder

Genetics and evolutionary change

1. Identify two environmental factors that can influence phenotype in humans.
2. Describe a trait of an organism other than a human that is influenced by an environmental factor.
3. Explain how skin colour can be influenced by both genes and the environment.
4. Discuss what your skin colour could help you to determine about your ancestors.

Communication

see page 429

A student conducted a survey into the phenotype of everyone in their class. They found that 60 per cent of students could roll their tongue, 70 per cent had dimples, 20 per cent had blue eyes, 50 per cent had brown hair, and 10 per cent had a big toe that was shorter than their second toe.

1. Propose an appropriate way to compile and present this information clearly.
2. Construct your presentation using a digital technology.
3. Measure and record the height of everyone in your class and construct a graph showing the data you have collected. See pages 457–61 of the Science how-to section for help with constructing graphs.
4. Present your graph to another student in your class and compare their graph to yours. Propose reasons to explain any differences.

In context

Another trait controlled by our genes is hair colour. Propose why the hair colour of humans is more likely to be a polygenic trait, rather than a monogenic trait.

Success criteria

- I can identify that a number of factors can affect the expression of genes.
- I can identify the relationship between the environment, genes and phenotype.

5.7 ▸ Mutation and genetic variation

Learning intention

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

- describe what a mutation is
- explain how mutations affect genetic variation.

Key terms

chromosomal mutation: a mutation caused by a change to a large section of a chromosome

genetic diversity: the range of genes present within a population or species

karyotype: a picture of an organism's full set of chromosomes

mutation: an error in DNA that changes the DNA sequence, which can be caused by DNA replication, or cell division

point mutation: a mutation caused by a change to a single nucleotide base

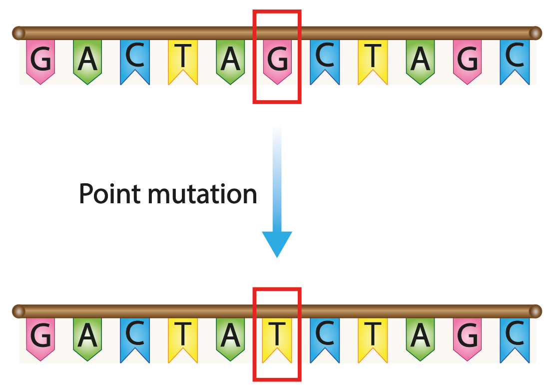
Content group: Variation and inheritance

If you were to put all your DNA end to end, it would reach to the Sun and back over 600 times! With that amount of DNA, it is not surprising that mistakes happen when it is copied or replicated. These errors can become **mutations**.

Errors can occur during DNA replication

During DNA replication, the existing strands of DNA act as templates for new strands to form. Even though the DNA replication process is very tightly controlled, mistakes can happen when the bases are being read or synthesised. These mistakes result in changes in the DNA being produced and are known as **point mutations**.

There are three main types of point mutation: substitution, insertion and deletion. In substitution, an incorrect base is inserted. In insertion, one or more extra bases are incorrectly inserted. In deletion, one or more bases are removed.



▲ **Figure 5.26:** A point mutation is a change to a single nucleotide base on a strand of DNA.

Errors can occur during cell division

When cell division occurs, chromosomes move around in the cells, and during meiosis, the chromosomes randomly swap sections of genetic material. If these processes occur incorrectly, it can cause a **chromosomal mutation**. There are several kinds of chromosomal mutation, as shown in Table 5.5.

Sometimes, chromosomes fail to separate correctly during cell division. Some cells may receive additional copies of whole chromosomes, while others may be missing them. This can occur during both mitosis and meiosis. When cells produced by meiosis contain additional or are missing chromosomes, this mutation can be passed from parents to offspring.

Other factors can cause mutations

Other factors that can disrupt DNA sequences and cause mutations include environmental factors such as ultraviolet radiation from the Sun, and chemicals such as cigarette smoke.

Table 5.5: Types of chromosomal mutations

Mutation	Description
Deletion	A section of the chromosome is removed, usually during crossing over in meiosis.
Duplication	A section of a chromosome is replicated twice and inserted into the chromosome.
Insertion	A section from one chromosome is incorrectly inserted into another.
Inversion	A section of a chromosome is inserted upside-down during crossing over.
Translocation	A section of a chromosome breaks off and reattaches to a different section of another chromosome.

Table 5.6: The impacts of mutation

Impact	Description	Examples
Beneficial	The mutation causes a change that improves the organism's survival.	The production of an enzyme that confers the ability to digest lactose (sugars) in milk
Harmful	The mutation causes a change that negatively impacts the organism's survival.	Cystic fibrosis – a disease in humans results in the build-up of sticky mucus in the lungs Trisomy 21 (Down syndrome) – a person has an extra copy of chromosome 21 (three instead of two)
None	The mutation does not cause a change to the organism.	Substitutions of a single base that results in the same protein being formed, producing no change to the organism

Effects of mutations

The effect of a mutation depends on its type and location. It may be beneficial or harmful, or have no effect (Table 5.6).

All mutations result in a change to the genetic sequence of DNA. This means they can affect **genetic diversity**. Beneficial mutations have a higher chance of being passed on to future generations. Over time, this increases the genetic diversity of the species.

Harmful mutations can also be passed on if they occur in the gametes. This is how children of healthy parents can be born with conditions such as cystic fibrosis and trisomy 21. Harmful mutations can also kill organisms. If this occurs frequently, the genetic diversity of a species can be decreased.

Karyotypes are pictures of an individual's chromosomes (Figure 5.27). To get this picture, cells containing condensed chromosomes are stained and examined under a microscope. An image of the chromosomes is taken, and each chromosome is cut out, placed next to its pair and numbered. The largest chromosome is chromosome 1. By observing the appearance and number of chromosomes, scientists can check for chromosomal abnormalities.

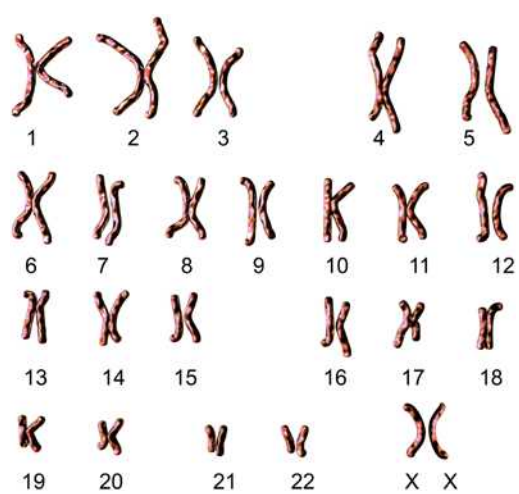


Figure 5.27: The XX chromosome pair in this karyotype shows that the person is female. Males have an XY chromosome pair instead.

Learning Ladder

Genetics and evolutionary change

1. Identify the three types of point mutation.
2. Describe one type of point mutation and one type of chromosomal mutation.
3. Explain how genetic diversity can be affected by mutations.
4. Discuss how mutations that cause disease show that genetics pass from parents to offspring.

Communicating

see page 429

1. Select an appropriate way to organise information about the types of chromosomal mutations.
2. Construct a digital table that compares point and chromosomal mutations.
3. Construct a scientific poster on the impact of a named mutation. (See the Science how-to section on pages 436–37.)
4. Present your poster to one of your peers, and listen to their presentation. Provide three pieces of feedback to your peer about how they could improve their poster.

In context

Use secondary-sourced data to identify another beneficial and another harmful mutation that affects humans. Explain the cause of each mutation, and describe its impact on us.

Success criteria

- I can identify a range of mutations.
- I can explain how mutations affect genetic diversity.

5.8 ▸ Genotypes and phenotypes

Learning intention

At the end of this lesson, I will be able to outline the connection between genotypes and phenotypes, and link this to Mendelian inheritance.

Key terms

dominant allele: an allele that only requires one copy to be seen in a phenotype

heterozygous: a genotype of two different alleles

homozygous: a genotype of two of the same allele

recessive allele: an allele that requires two copies to be seen in a phenotype

Content group: Variation and inheritance

Genes are responsible for the physical characteristics of all living things. We can use our understanding of genetics to predict patterns of monogenic inheritance.

Alleles can be dominant or recessive

When a gene for a single trait has two alleles, we can often predict the gene's inheritance pattern. One allele of the gene is usually dominant over the other and has more influence on how that gene is expressed.

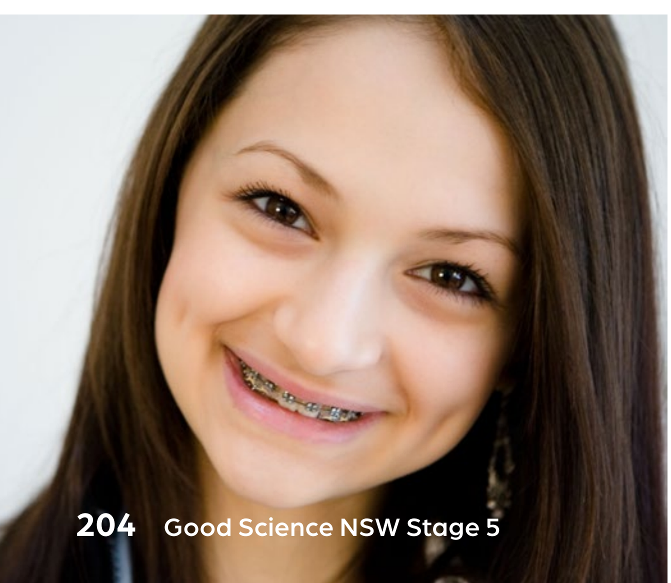
An organism that is **heterozygous** for a gene has a copy of the **dominant allele** and a copy of the **recessive allele**. They will display characteristics of the dominant allele. An organism that is **homozygous** for a gene has either two copies of the dominant allele or two copies of the recessive allele.

We represent the alleles of a gene as letters – an upper-case letter for a dominant allele and a lower-case letter for a recessive allele (Table 5.7).

Table 5.7: How different genotypes are represented in monogenic inheritance traits.

Genotype description	Genotype	Phenotype
Homozygous dominant	AA	Dominant characteristic
Heterozygous	Aa	Dominant characteristic
Homozygous recessive	aa	Recessive characteristic

Figure 5.28: Dimples are a dominant trait, so the person in this image must have a genotype of DD or Dd, not the recessive dd genotype.



Mendel determined monogenic inheritance patterns

In the 1860s, Austrian biologist Gregor Mendel bred more than 30 000 pea plants to test patterns of inheritance. He manually pollinated the plants by using a paintbrush to control which plants were bred together. He studied the occurrence of specific traits that could be expressed in two ways: height (tall or short), seed shape (round or wrinkled), flower colour (purple or white) and pod colour (yellow or green). By crossing 'pure-breeding' (homozygous) plants with the same traits, he was able to show that when two plants that had only one gene for a trait are crossed, all of their offspring have the same trait.

Mendel's work with cross-breeding plants allowed him to better understand inheritance. When he crossed a homozygous dominant plant with a homozygous recessive plant, all the offspring displayed only dominant traits. When he bred two of the 'hybrid' (heterozygous) plants from this first (F_1) generation together, three-quarters of the offspring displayed the dominant trait and one-quarter of them displayed the recessive trait. This three-to-one (3:1) ratio was consistently displayed when heterozygous offspring were bred together, no matter what trait was being studied. This is shown for pod colour in Figure 5.29.

Table 5.8: Common inheritance patterns in monogenic traits in Mendel's pea plants and in humans

Characteristic	Alleles	Dominant phenotype	Genotypes for dominant phenotype	Recessive phenotype	Genotype for recessive phenotype
Pea plant height	Tall (T) Short (t)	Tall	TT, Tt	Short	tt
Seed shape	Round (R) Wrinkled (r)	Round	RR, Rr	Wrinkled	rr
Pod colour	Green (G) Yellow (g)	Green	GG, Gg	Yellow	gg
Dimples	Dimples (D) No dimples (d)	Dimples	DD, Dd	No dimples	dd
Widow's peak	Peak (W) No peak (w)	Peak	WW, Ww	No peak	ww

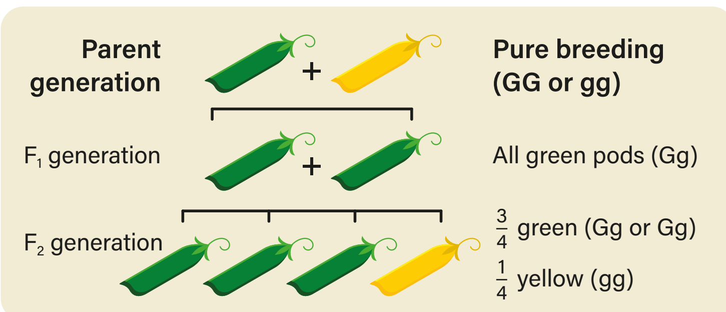


Figure 5.29: Mendel showed that when hybrid plants were cross-bred, the dominant trait was displayed over the recessive trait in a 3:1 ratio. In this experiment, the parent generation are pure breeding, either GG or gg. The F_1 generation is the first generation bred from the pair of parents and are all hybrid (Gg). The F_2 generation is the second generation and contains three Gg (dominant) individuals and one gg (recessive) individual..

Learning Ladder

Genetics and evolutionary change

1. Identify three characteristics of Mendel's pea plants, and the genotype required for the recessive phenotype to be displayed for each.
2. Describe how a person's genotype can affect whether their phenotype includes dimples.
3. Explain how Mendel was able to examine the genetics of the pea plants, despite not being able to view their DNA.
4. Discuss how Mendel's pea plant experiments provide evidence that organisms inherit and pass on genetic characteristics over generations.

Processing data and information

see page 412

A student wanted to replicate Mendel's pea plant experiments into flower colour. She manually pollinated two hybrid pea plants, grew eight offspring plants and observed their flower colours. Six of the plants had purple flowers and two had white flowers.

1. Propose the number of purple and white flowers the student should have seen in their eight plants. Does it match the data she has collected?
2. Use the student's data to construct an appropriate graph.
3. Calculate the ratio of purple- to white-flowered plants.
4. Explain whether the student's data supports or refutes the ratios Mendel observed in his investigations.
5. Propose a way that the student could improve the reliability of her data, and explain whether this may affect the results she obtains.

In context

Petal colour in some species of flower is controlled by a single gene with two alleles, but the petals can be one of three distinct colours. Using research, identify the name of this type of gene expression, and predict whether this type of inheritance would follow the same ratios as the inheritance patterns Mendel explained. Give a reason for your prediction.

Success criteria

- I can outline the relationship between genotypes and phenotypes.
- I can explain Mendelian inheritance patterns.

5.9 ► Punnett squares and pedigrees

Learning intention

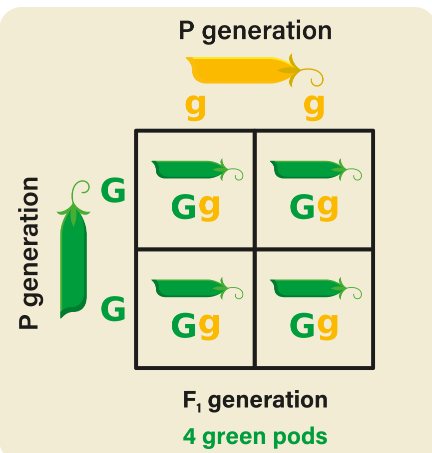
At the end of this lesson, I will be able to model and predict inheritance patterns using Punnett squares and pedigrees.

Key terms

pedigree chart: a chart that shows the inheritance of a trait through generations of a family

Punnett square: a diagram that shows the possible genotypes of offspring

Content group: Variation and inheritance



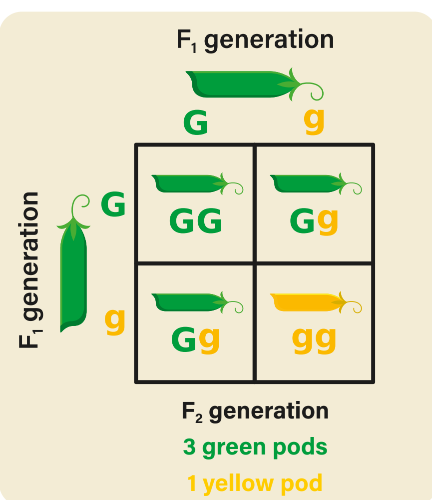


Figure 5.30: Punnett squares show the possible genotypes of offspring from two parents. These Punnett squares show the genotypes of Mendel's pea plant experiment into pod colour.

We can use two ways to map traits in families to predict the likelihood of offspring having specific phenotypes: Punnett squares and pedigrees.

Punnett squares show single crosses

A **Punnett square** is a diagram showing a box with four spaces that can be used to determine the possible genotypes of one generation of offspring from two parents. Up to four possible genotypes will be shown. The information inside the square can then be used to show the expected percentage (%) or ratio of offspring that have a particular genotype. Once the possible genotypes are known, they can be used to determine the possible percentage or ratio of phenotypes of offspring.

The different generations in a cross-breeding experiment are given different names:

- The original pair of parents are the P generation.
- The first generation produced from the P generation is the F_1 generation.
- The generation produced by cross-breeding among the F_1 generation is the F_2 generation.

Punnett squares can predict the genotypes of offspring

To construct a Punnett square:

- draw the outline of your Punnett square
- select a trait and assign the allele a letter
- identify the genotype of the two parents (P): are they homozygous dominant, heterozygous or homozygous recessive?
- place the alleles of one parent down the left-hand side of the box
- place the alleles of the second parent across the top of the box
- fill in the four boxes in the table by matching up the allele from the left and the allele from the top. Always write the capital letter allele first if there is one.

Once your Punnett square has been drawn, you can determine the percentage or ratio of the possible genotypes, and then phenotypes of offspring from the two parents. For example, consider the Punnett squares in Figure 5.30.

Square 1: P generation

Both parents are homozygous: one for green pods (GG) and one for yellow pods (gg). All potential offspring must inherit a G allele from one parent and a g allele from the other parent, meaning that 100 per cent of the offspring genotypes will be Gg. This means they are all heterozygous and all have the dominant green phenotype.

Square 2: F_1 generation

Both parents are heterozygous Gg – they all have green pods. The offspring will be GG (25 per cent), Gg (50 per cent) and gg (25 per cent). Therefore, the genotypic ratio is 1 GG : 2 Gg : 1 gg.

The phenotypes are green (75 per cent) (remember, heterozygous genotypes always show the dominant trait) and yellow (25 per cent). Therefore, the phenotypic ratio is 3 green : 1 yellow.

Pedigree charts show traits passed down through families

A **pedigree chart** shows which family members over generations have a particular trait or phenotype. Pedigree charts can be used to identify whether a trait is dominant or recessive. Males are represented by a square and females by a circle, and shading indicates the presence of the trait. A horizontal line between them means they are a mating pair, and a vertical line coming from the mating line means they have offspring. Generations are numbered in Roman numerals on the left of the chart. Individuals in each generation are also numbered. For example, in Figure 5.31, the filled-in circle in the first generation is Individual I-1.

Pedigrees can be used to track the inheritance of non-infectious diseases, such as haemophilia (a blood-clotting disease) and colour blindness. These diseases are expressed by a recessive gene that is present specifically on the X chromosome. If a female (with two X chromosomes) has a single copy of the recessive allele, they can be a carrier of the disease, but not have the disease itself because the other X chromosome has the dominant allele. However, males have one X chromosome and one Y chromosome. If their X chromosome has the allele for the disease, then they will have the disease. Males cannot be carriers for recessive conditions that are present on the X and Y chromosomes. That is why these diseases are more commonly seen in males.

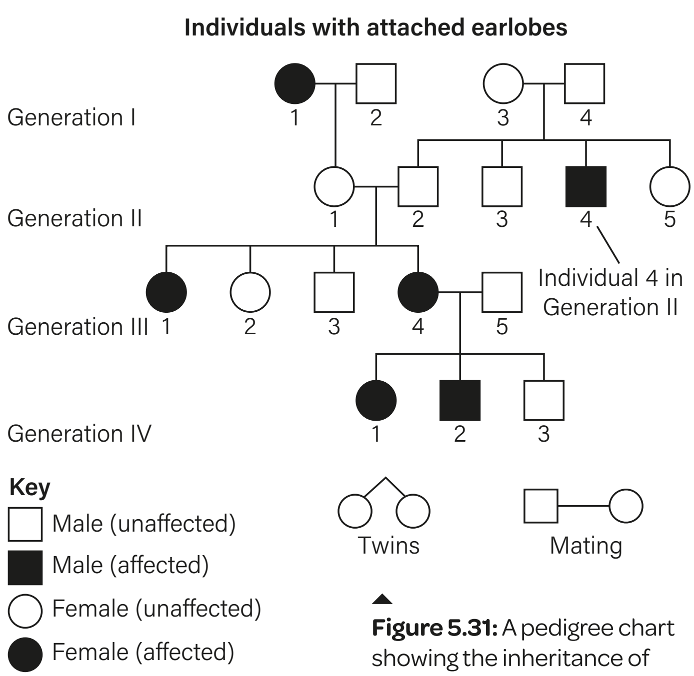


Figure 5.31: A pedigree chart showing the inheritance of attached earlobes through generations of a family

Pedigree charts can give us information about genotypes

In pedigrees, patterns in the occurrence of specific traits can give us hints about whether the trait is dominant or recessive.

For example, if two parents who are both affected by a particular trait (filled-in shapes) produce an offspring who is unaffected (not filled in), then the trait can be predicted to be dominant. Each parent must be heterozygous for the trait and have one copy of the recessive allele. The unaffected offspring received two recessive alleles, one from each parent.

However, if both parents are unaffected by a particular trait and produce an offspring who is affected, then the trait can be predicted to be recessive. Both parents were heterozygous for the trait and carried the recessive allele for it. The offspring received both recessive alleles and so is affected.

If the patterns of pedigree charts look more complicated than this, then a different type of inheritance than just a monogenic trait might be occurring. Sex-linked conditions might appear more often in males, and polygenic trait patterns can be very difficult to distinguish.

Pedigrees and Punnett squares can be constructed from written information

We can use written information based on observations of phenotypes to construct pedigrees showing inheritance through generations of a family.

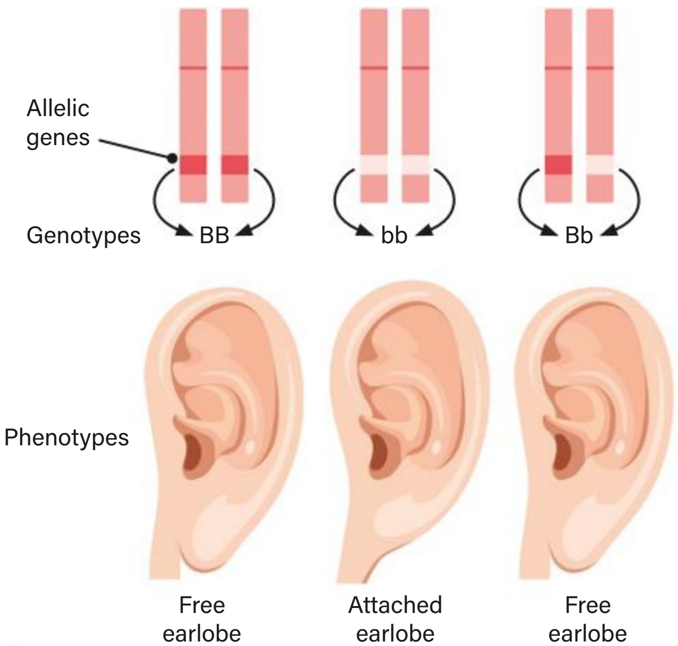


Figure 5.32: Earlobe attachment is controlled by a specific gene. These allele combinations can be tracked and mapped over generations using a pedigree chart, like the one in Figure 5.31.

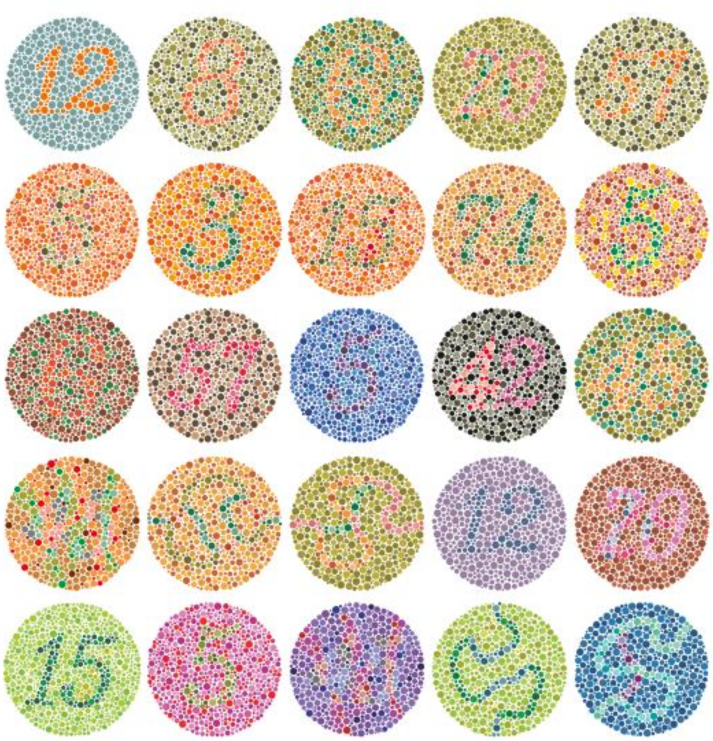


Figure 5.33: Males are more likely to inherit colour blindness than females because it is carried on the X sex chromosome. These charts are used to test for colour blindness; each contains a symbol or an image. People with different types of colour blindness may not be able to see all the different numbers and shapes.

From there, we can predict the likelihood of particular phenotypes occurring, by using a Punnett square to show possible genotypes and linking these to their correct phenotypes.

For example, in Section 5.8 we saw that dimples are a monogenic trait. People with dimples have the dominant (D) allele, while those without dimples have the recessive (d) allele, and *must* have the homozygous recessive genotype (dd).

The following observations were made about a family. Kate was looking at photos to investigate her family history. She noticed that some family members had dimples and others did not. Her mother does not have dimples, and neither does her mother's mother, but her grandfather does. On her father's side, her father and grandmother both have dimples, but her grandfather does not. Kate does not have dimples, but her two brothers do. Kate wondered if her child would have dimples. Her husband and his mother have dimples.

We can construct a pedigree to show the appearance of dimples in Kate's family by following these steps:

1. Identify the number of generations.
   Three: Kate, her parents and her grandparents.
2. Represent each individual in the information with a symbol – circles for females and squares for males. Align the circles and squares with the generation labels.
3. Draw a line between Kate and her husband, between Kate's parents, and between each set of grandparents, to show that they have had, or may have, offspring.
4. Connect Kate to her two brothers by drawing a line from the horizontal line between her parents and then joining it to a horizontal line that connects to each sibling.
5. Construct a key identifying affected and unaffected males and females.
6. Shade those symbols that represent a person with dimples.
7. Number the circles and squares, so that each individual can be easily identified. Figure 5.34 shows a constructed pedigree.

Once the pedigree has been constructed, you can use a Punnett square to determine the likelihood of Kate's offspring having dimples. To do this, determine the genotype of Kate and her husband and place them on the outside of a Punnett square (Figure 5.34).

1. As Kate does not have dimples, her genotype *must* be recessive (dd).
2. Kate's husband has dimples, so he must have at least *one* dominant allele (D). However, his father does not have dimples, so his genotype would be homozygous recessive (dd). As Kate's husband would have one copy of the recessive allele from this parent (d), his genotype must be heterozygous (Dd).
3. Construct the Punnett square so that the genotypic and phenotypic ratios can be calculated, and the likelihood determined of Kate's children having dimples.

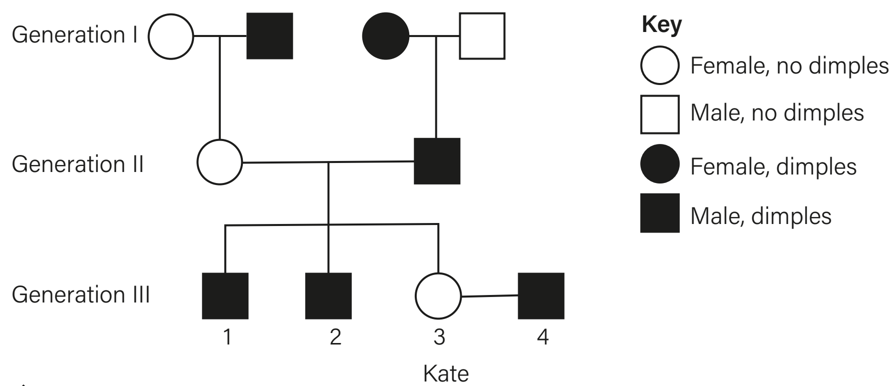


Figure 5.34: A pedigree representing Kate's family and those family members that have dimples.

	D	d
d	Dd	dd
d	Dd	dd

1Dd : 1dd

Figure 5.35: A Punnett square showing the possible offspring of Kate and her husband. It shows a genotypic ratio of 1 Dd: 1dd, and a phenotypic ratio of 1 dimples : 1 no dimples. This means there is a 50 per cent chance of Kate's children having dimples.

Learning Ladder

Genetics and evolutionary change

1. Identify two mechanisms for tracking genetic patterns of inheritance.
2. Describe why pedigrees are more useful for showing multiple generations of genetic inheritance.
3. Two parents who are heterozygous for dimples (a dominant trait: D) are planning to have a child. Explain how you could predict, using a Punnett square, the likelihood of the child *not* having dimples.
4. Discuss how pedigrees and Punnett squares can provide evidence of genetic inheritance patterns.
5. Evaluate how effectively pedigrees could be used to show evidence of changing genetics over many generations.

Processing data and information *see page 412*

A student wants to track the inheritance of widow's peaks in his family. (A widow's peak is a V-shaped hairline, with the peak in the centre of the forehead.) He has a widow's peak, but his sister does not. His parents both have widow's peaks. His grandparents on his mother's side both have widow's peaks. However, on his father's side, only his grandfather and an uncle have a widow's peak.

1. Construct a pedigree showing this information. Make widow's peak the affected trait.
2. Using your pedigree, propose whether widow's peak is a dominant or recessive trait. Give a reason for your choice.
3. Calculate the percentage of individuals with and without a widow's peak in the pedigree.
4. Use your percentages to identify the ratio of individuals with a widow's peak to those without a widow's peak. Does this ratio support or refute Mendelian inheritance ratios?
5. Propose a way that this student could improve the accuracy of his data.

In context

Haemophilia is a sex-linked (carried on the sex chromosome) condition that has been linked to the British royal family. Using information from this section and secondary research, propose which members of the royal family (male or female) would be more likely to inherit the condition, and explain your choice. Include a pedigree or Punnett square to support your explanation.

Success criteria

- I can construct Punnett squares to model and predict inheritance patterns.
- I can construct pedigrees to model and predict inheritance patterns.

5·10 ▸ Genetic technologies

Learning intention

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

- identify examples of genetic technologies
- discuss the applications of genetic technologies in different fields.

Key terms

biotechnology: using living organisms to develop products

recombinant DNA: DNA that has been formed by inserting or combining genes from different organisms

transgenic organism: a living thing that contains recombinant DNA

Content group: Genetic technologies

Developments in science and medicine have led to the emergence of new technologies known as biotechnologies. More specific are genetic technologies, which enable us to alter organisms on a genetic level.

Biotechnology develops products from living things

Biotechnology is any use of living things to develop products or to change existing ones. Biotechnology has been used for hundreds (if not thousands) of years in farming and medicine. Farmers have cultivated plant species by selecting traits over time. For example, carrots in the wild used to be purple and sometimes yellow. However, by breeding together yellow and white mutations of carrots, farmers were able to produce orange carrots, which have a sweeter taste. Now, after many years of selective breeding, most carrots are orange.

Genetic technologies alter genetic codes

Since 1973, scientists have been investigating ways to alter the DNA of organisms. This has led to a specific type of biotechnology known as 'genetic technology'. With genetic technologies, the DNA of organisms is deliberately altered to improve the organism or to make it more useful to us. Some genetic technologies are used to help prevent genetic disorders. Table 5.9 summarises two genetic technologies and identifies some of the products that can be made by using them.

Table 5.9: Products made from whole organism cloning and recombinant DNA

Genetic technology	How it works	Items produced with this technology
Whole organism cloning	▪ DNA from a donor cell is extracted and placed into an egg cell that has had its genetic material removed. An electric shock fuses the materials and causes the egg cell to start dividing. ▪ The egg cell is transplanted into the uterus of an organism to develop, resulting in the birth of a cloned organism.	▪ Sheep, cattle and other livestock
Recombinant DNA	▪ Target gene(s) are extracted from the source DNA and inserted into a bacterial plasmid using special enzymes. This is then inserted into a bacterium, to replicate many copies of the gene. These genes can then be used in various ways.	▪ **Transgenic organisms** such as the enviro-pig ▪ Transgenic crops such as BT cotton and golden rice ▪ Medicines such as insulin

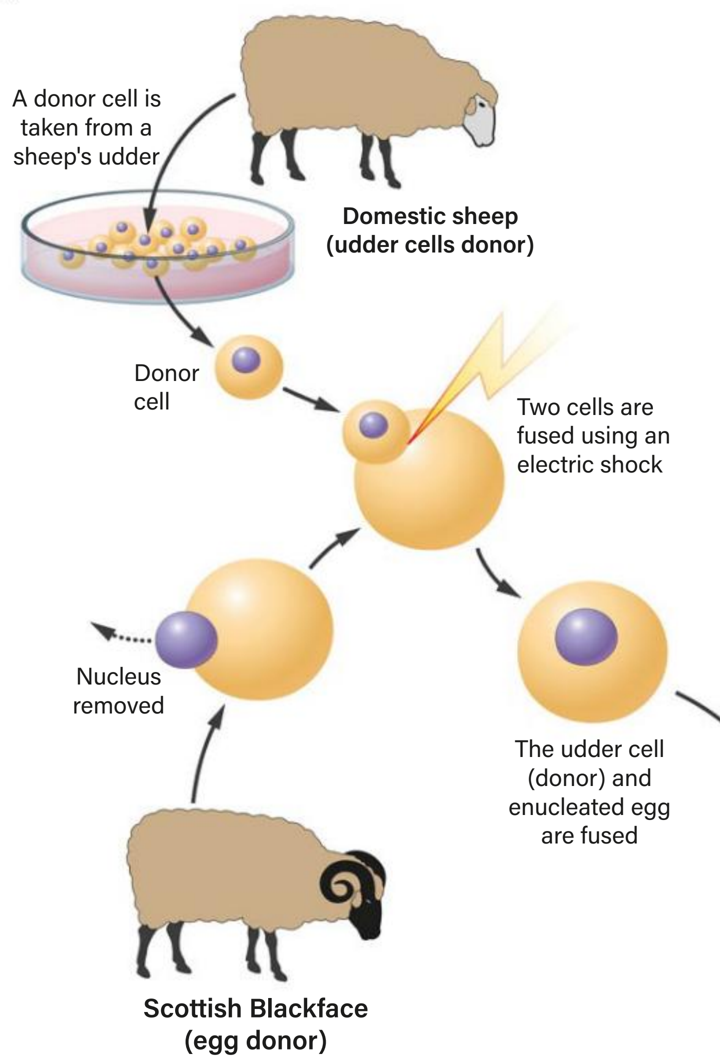
Whole organism cloning produces genetically identical organisms

As seen in Table 5.9, there are two different ways of producing organisms by using genetic technologies. Figure 5.36 shows the first successful whole organism cloning procedure, which produced Dolly the sheep. In 1996, the nucleus of a mammary gland cell was taken from a Finn-Dorset sheep and inserted into an egg cell whose genetic material had been removed. The cell was placed into a test tube, and cell division was started with a spark of electricity. After six days, normal development of the cell was confirmed, and the embryo was transferred into a surrogate mother, to develop into a cloned sheep offspring.

Dolly the sheep was born on 5 July 1996. She lived as a normal sheep, having her own offspring, and died at the age of six in February 2003, when she was found to have tumours in her lungs. This raised questions over whether cloned organisms live as long as naturally conceived organisms. Since then, studies conducted by scientists have suggested that there is not sufficient evidence to say that cloned organisms die earlier than non-cloned organisms.

Even though Dolly, and many organisms since, have been created by whole organism cloning, this has not resulted in fields full of completely identical-looking organisms! This is because even though the clones are genetically identical, their development in the womb, their diet and their environmental exposure affect how their genes are expressed, resulting in variations in coat colour and patterns.

Figure 5.36: Dolly the sheep was the first mammal to be successfully cloned using whole organism cloning.



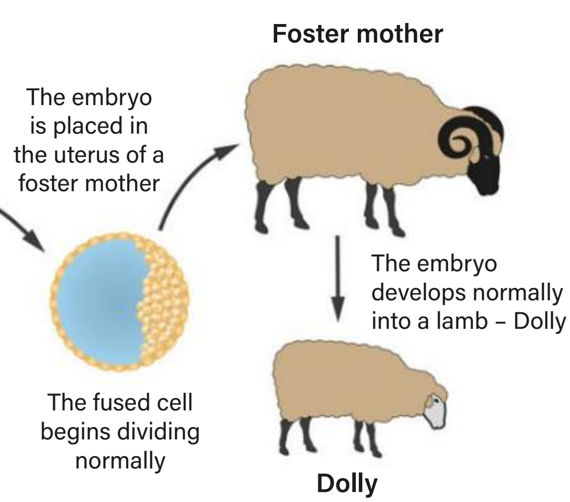
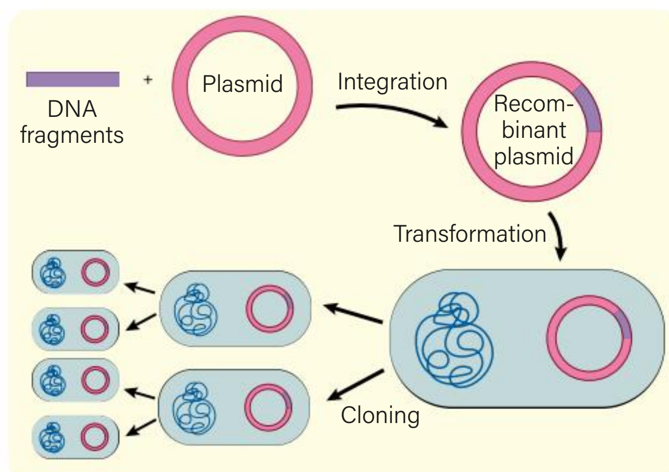


Figure 5.37: Bacteria are used to replicate desired genes so that they can be inserted into the genetic code of other organisms.



Genetic technologies have many applications

The applications of genetic technologies include conservation, agriculture, industry and medicine.

Conservation

For years, Tasmanian devil populations have been plagued with a rare, transmissible cancer that produces tumours on their face. These tumours eventually kill the animal.

Some Tasmanian devils have developed a gene that provides them with resistance to facial tumour cancer. Using **recombinant DNA** technology, scientists will be able to introduce this gene into more Tasmanian devils than they would be able to by using selective breeding measures.

Figure 5.38: Genetic technologies may save the Tasmanian devil from facial tumour cancer,

Agriculture

BT cotton is a transgenic organism that has been produced by recombinant DNA technologies to give it natural resistance to pests. This reduces the need for pesticides and increases the yield of crops because they are no longer being eaten by pests.

Golden rice is also produced by recombinant DNA technologies; however, golden rice is deliberately made to produce vitamin A, to address a dietary deficiency in countries whose main source of carbohydrates is rice. This helps to prevent deficiencies within large populations.

Animals can also be produced by genetic technologies. AquAdvantage salmon are transgenic salmon that have been produced to grow faster than normal. A gene is ‘switched off’, allowing them to grow all year round, which increases the size of the fish and speeds up the growth process. Hence, the availability of fish for purchase and consumption is increased.

Industry

Scientists are currently exploring using genetically engineered enzymes to extract certain minerals and ores from rocks, which would reduce the environmental impact and waste from mining.

Figure 5.39: Natural resistance to pests in transgenic organisms such as BT cotton (left) can reduce the need for chemicals and increase yields, while the addition of vitamins to crops like golden rice (right) can help to prevent dietary deficiencies.

Medicine

Recombinant DNA is used in medicine to help produce products such as insulin. As shown in Figure 5.40, the gene for insulin production is inserted into bacteria, which then replicate and produce insulin that can be used as an alternative to synthetic insulin for people with diabetes.

Gene therapy is a genetic technology that can be used to help manage, or sometimes even cure, genetic diseases (Figure 5.41). By cloning and then introducing 'healthy' genes into human cells, which divide and produce more healthy cells, conditions such as haemophilia and leukaemia can be treated.

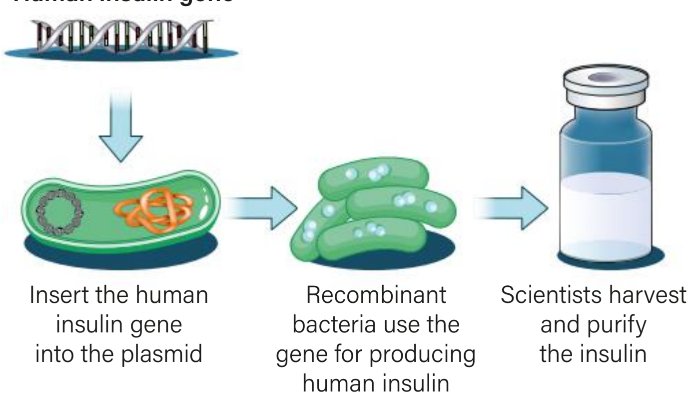


Figure 5.40: Gene cloning can be used to create recombinant DNA in organisms that then produce products for medicine, such as insulin for diabetics.

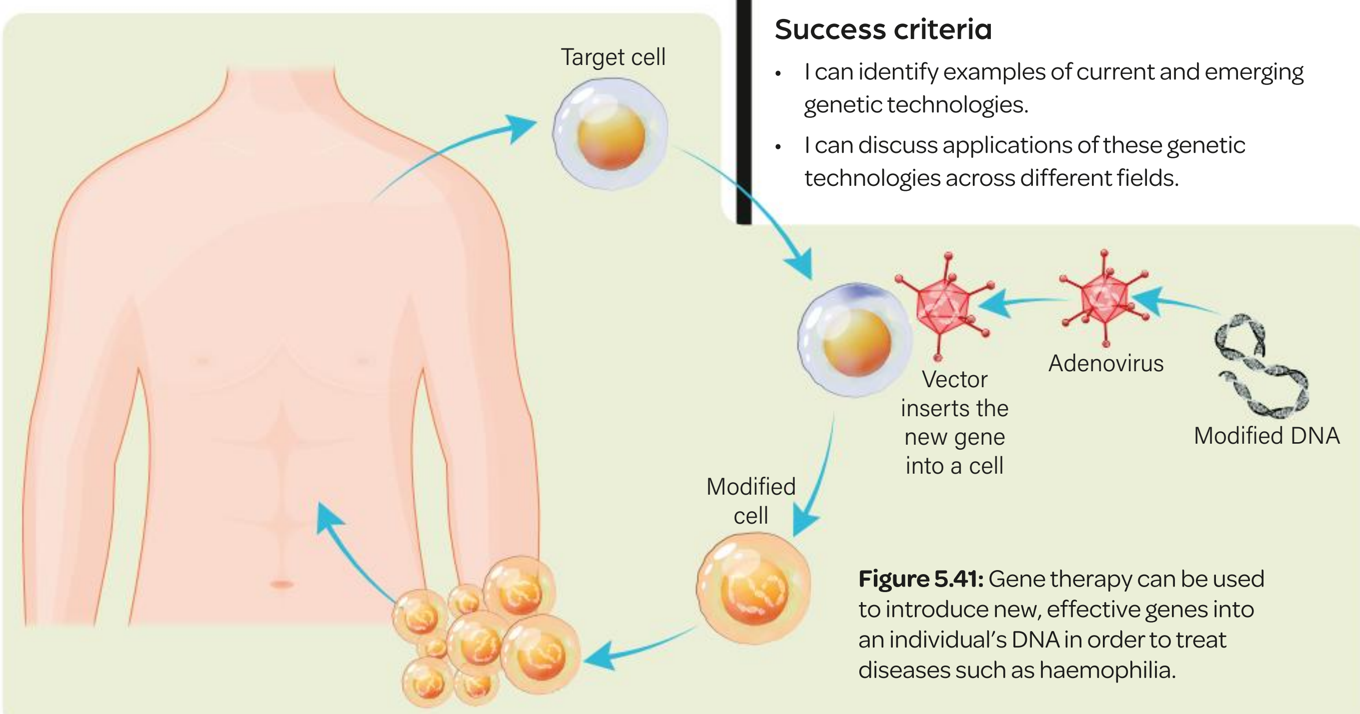


Figure 5.41: Gene therapy can be used to introduce new, effective genes into an individual's DNA in order to treat diseases such as haemophilia.

Learning Ladder

Genetics and evolutionary change

1. Identify three uses of gene cloning in different industries.
2. Describe the benefits of one of the technologies you identified in Question 1.
3. Explain how the use of recombinant DNA can be used on one plant and one animal in agriculture.
4. Discuss how conservation efforts could affect the genetics of the Tasmanian devil.
5. Evaluate how the overuse of whole organism cloning could affect the biodiversity of livestock over time.

Communicating

see page 429

1. Describe a way that you could communicate information on whole organism cloning to other students in your year group.
2. Construct a digital table that could be used to summarise the use of recombinant DNA technologies in different industries.
3. Construct a flow chart showing the steps used to clone an organism or a gene.

In context

Conduct research and find two additional examples of diseases that can be managed or treated by gene therapy, and explain how it is able to manage/treat each disease.

Success criteria

- I can identify examples of current and emerging genetic technologies.
- I can discuss applications of these genetic technologies across different fields.

5·11 ▸ Genetic testing

Learning intention

At the end of this lesson, I will be able to discuss the applications and considerations associated with genetic technologies.

Key terms

economic consideration: a factor that takes into account the costs to individuals and groups

ethical consideration: a factor that takes into account what is right and what is wrong

social consideration: a factor that affects society and the people within society

Content group: Genetic technologies

There are many applications of biotechnology. Each has advantages and disadvantages. Biotechnology also has a huge impact on society, and so the social and ethical considerations of each use must be discussed. **Social considerations** are factors that affect society and people, while **ethical considerations** are factors that take into account what is right and what is wrong. **Economic considerations** take into account the financial cost of these technologies to individuals and groups.

Tracing ancestry

Genetic ancestry testing uses genetic technology to screen the DNA of individuals. By looking at specific sections of DNA and analysing it for patterns, links can be made to a person's ancestry, giving insight into their background.

Advantages

Knowing about your ancestry can provide insights into risk factors you might have for specific diseases and conditions.

Disadvantages

Ancestry tracing relies on some assumptions and does not take into account migration between populations.

Social considerations

Not everyone can access testing kits, so it is not an equitable process. Should people be prevented from knowing their ancestry because they cannot access a testing kit?

Economic considerations

Home-testing kits can be expensive, especially when kits from different companies sometimes provide different results for the same person.

Ethical considerations

Many companies require you to agree to allow them to store your genetic information. This means that information about you could potentially be accessed without your consent.

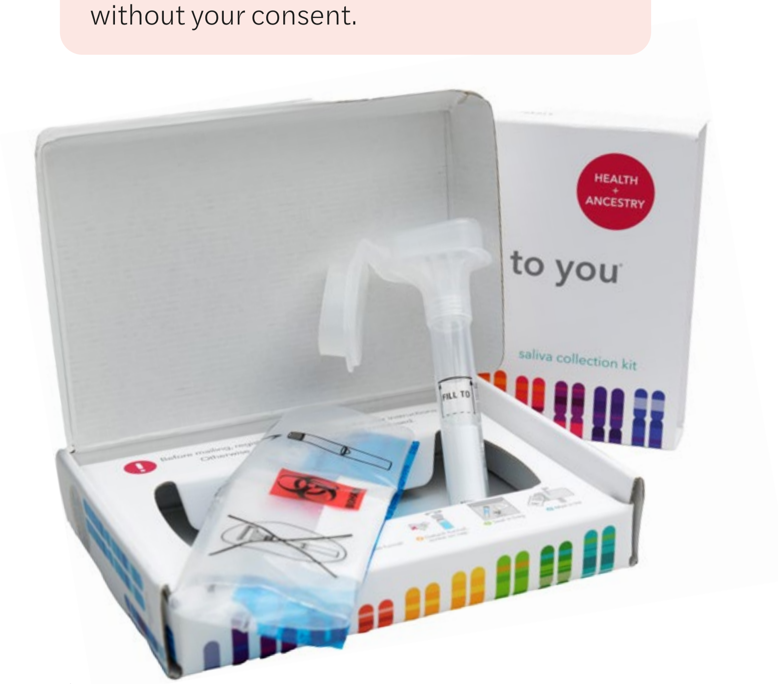


Figure 5.42: Home-testing kits can be used to collect samples of your DNA, which can then be sent to laboratories. When processed, your DNA can provide insight into your ancestry.

Genetic counselling

Health professionals who specialise in genetic counselling have experience in understanding genetic screening tests, counselling and health screening. They assist people to understand genetic screening tests, including the implications of the test, and help those who have undergone genetic screening to deal with the implications for them and their families. Genetic counselling can be undertaken when planning a pregnancy and when screening for cancers and other genetic conditions.

Advantages

Genetic counselling helps people to understand and make informed decisions about the results of genetic tests. It provides individuals and families with a support network to help them manage negative news about genetic screening tests.

Disadvantages

Genetic counselling can cause high levels of stress and anxiety in individuals who are already struggling to comprehend difficult diagnoses, so that discussing results and options can quickly become overwhelming.

Social considerations

Genetic counselling provides an additional level of support and understanding when navigating genetic screening for diseases and inherited conditions, reducing the risk of adverse reactions from affected individuals.

Economic considerations

Counselling options are not free. In countries where health care can be expensive, support can be limited to those who can afford it.

Ethical considerations

A lack of equitable access to health care can prevent people from accessing support, which can be isolating for those affected.

Figure 5.43: Where someone lives can have a major influence on their access to medical treatments that use new genetic technologies.

Population screening

Population screening uses genetic technologies to test for specific diseases or disease markers in a target group. This can help to show patterns of diseases across larger populations, which increases the chances of identifying at-risk individuals earlier and helps with disease diagnosis and treatment.

Advantages

Population screening helps to identify large-scale patterns in diseases and genetic risk markers for diseases across many populations, meaning that diagnosis and treatment can be offered earlier.

Economic considerations

Population screening can be expensive, which puts a strain on the budgets of governments and organisations trying to fund large-scale testing pools for the population.

Disadvantages

Not all conditions can be picked up by genetic screening, so some conditions may be missed if testing is relied upon too heavily.

Ethical considerations

Much like ancestry tracing, population screening pools information about individuals and their genetics into a database so that it can be analysed to find patterns. This means that personal information about genetics could be accessed without someone's consent.

Social considerations

Limited access to health care and testing facilities can mean that some individuals do not have the opportunity to access and participate in screening tests.

Figure 5.44: Scientists use precise DNA mapping technologies to screen for specific traits and disease markers, which become apparent in DNA profiles.

Cancer treatment

Gene transfer technology can be used to treat some cancers, either by introducing new genes into the cancerous cell that slow or stop its growth or by surrounding it with slower growing tissue, causing it to die.

Advantages

Targeted therapy reduces the need for harmful treatments such as chemotherapy and radiation therapy, reducing the side effects from secondary illnesses.

Disadvantages

Isolating and cultivating genes that can be introduced to target specific cancers takes a long time, so this treatment is not readily available for all cancer types.

Social considerations

As this is a newer technology, gene therapy is often only available at specific health-care centres, limiting accessibility for large portions of the population.

Economic considerations

Testing and development of gene therapies for different cancers costs a lot of money. This means that governments need to allocate funding for this research, otherwise organisations may be left dependent on donations to fund their research.

Ethical considerations

Each treatment needs to go through multiple rounds of testing, including human trials. In areas where health care is not readily available, or where it is costly, individuals may feel forced into trial studies in order to access lifesaving treatments, even if they are unsure about whether they wish to participate.

Learning Ladder

Genetics and evolutionary change

1. Identify three uses for genetic technologies, and describe an advantage and a disadvantage of each.
2. Describe how genetic technologies can be used to treat cancer.
3. Explain how population screening can be used to provide insight into disease patterns.
4. Discuss how genetic counselling can help individuals to make more informed decisions about their health.
5. Evaluate the use of genetic technologies for learning about your ancestry.

Processing data and information *see page 412*

1. Construct a table to show the advantages and disadvantages of the use of genetic technologies for each application discussed in this section.
2. Use the advantages and disadvantages you identified in Question 1 to justify continuing research into these areas.
3. Calculate the distance between each of the towns listed in Figure 5.43.
4. **a** If the average speed by car between these towns is 90 km h^{-1}, calculate how long it would take to get from Goulburn to Melbourne.
   b Propose what impact this might have on Goulburn residents who require genetic testing services that are only available in Melbourne.

In context

Genetically modified crops (GMOs) are created by genetic technologies. Using the information you have learnt previously as well as secondary sources, discuss the advantages, disadvantages, and social, economic and ethical considerations of using GMOs.

Success criteria

- I can discuss the implications of several applications of genetic technologies.

▲
Figure 5.45: Giraffes' long necks are thought to be the result of natural selection.

Learning intention

At the end of this lesson, I will be able to explain how natural selection causes changes within and between populations.

Key terms

abiotic: non-living

isolation: when a population is cut off from others

natural selection: the process in which organisms that are better suited to their environment tend to survive and reproduce, passing their traits on to further generations

population: a group of organisms of the same species that live and interact within the same area

selection pressure: a factor that can influence which traits are beneficial to the survival of organisms

variation: the difference between individuals in a species, in both genetics and phenotypes

Investigation 5.12

Natural selection in practice, page 533

Content group: The theory of evolution and evidence of natural selection

5·12 ▸ Natural selection

Have you ever wondered why giraffes have such long necks? Their long necks let them eat leaves from the highest trees that other animals cannot reach. Most scientists now think that giraffes got their long necks through a process called natural selection. A giraffe with a longer neck was much more likely to find food and to survive than a giraffe with a shorter neck. So, giraffes with long necks would be more likely to reproduce and pass on the genes for longer necks to the next generation.

Variation can occur through many processes

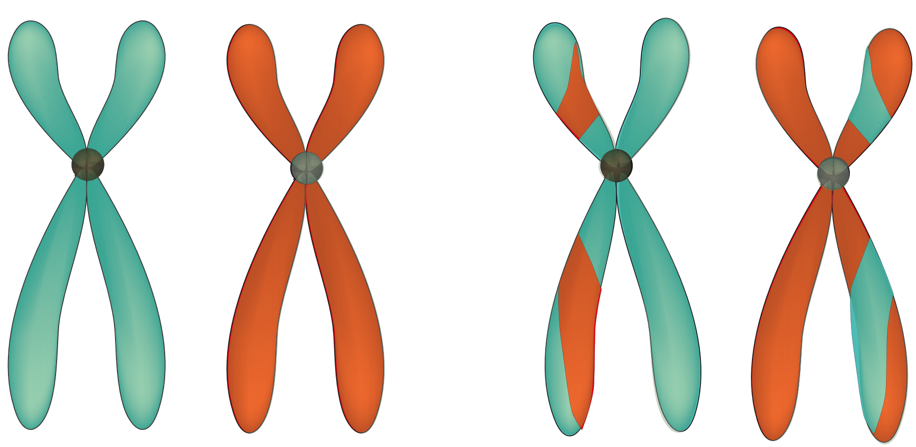
A key aspect of natural selection is **variation** within **populations**. Variations occur for several reasons, including mutation, meiosis and fertilisation.

Mutation

When a mutation occurs in a point or a section of an organism's DNA, it can have a number of effects. Whether it is a beneficial or a harmful mutation, it can be passed onto offspring, causing variations within the population.

Meiosis

In Section 5.5, we learnt that meiosis is cell division that forms gametes, which allow species to reproduce. During meiosis, chromosomes 'cross over' so that matching chromosomes randomly swap sections of their genetic code, making the resulting cells different from their parent cells. This unique combination of alleles can lead to variations between parents and offspring.



▲
Figure 5.46: Crossing over between homologous chromosomes can increase variations within a population.

Fertilisation

Part of the process of sexual reproduction is fertilisation, during which a male and a female gamete randomly fuse. A single new cell forms that then divides and develops into a new organism. The random fusing can lead to variations in offspring, who have a unique combination of alleles from their parents. In a population with a large number of alleles, a variety of phenotypes can be expressed.

Selection pressures affect species' survival

Ecosystems are complex and constantly changing. Various **selection pressures** within ecosystems can influence the survival of populations, as well as of individuals within populations. These factors include competition, predation, temperature changes and **isolation**.

Competition

All ecosystems contain limited resources. In some ecosystems, multiple species require the same resources, such as a common food source. This results in competition: the species compete to obtain and use the resource they both need. The population of the species that is more successful will rise, while the other population will fall.

Predation

Ecosystems include different plant and animal species. Animals that are omnivorous or carnivorous prey on other animals within the ecosystem. This is known as predation. An organism's ability to catch prey – or to avoid being prey – can influence its ability to survive. Prey can use camouflage and other measures to hide within its surroundings.

Temperature changes

Many **abiotic** factors can influence the survivability of an ecosystem, including soil conditions, exposure to sunlight and availability of water. One abiotic condition is becoming increasingly relevant across many ecosystems – changing temperatures. Continued influences of climate change are causing temperatures to shift in a number of ecosystems: from rainforests and deserts to glaciers and coral reefs. Many organisms, including plant life, struggle to survive against rapidly changing climates.

Isolation

Sometimes populations of a particular species move to different locations and become isolated. As a result, the two populations of the species can be exposed to different environmental conditions. Over time, this isolation can cause changes in each population.

Figure 5.47: An organism's ability to camouflage can help it to survive against predators, helping it to pass on its genetics to offspring. In this image, the paler moth is camouflaged against the pale background, so is more likely than the black moth to survive and pass on its genes.

Natural selection passes beneficial traits to offspring

Natural selection is the name given to the process of beneficial traits being passed from parents to offspring. Over time, natural selection can cause changes in the frequencies of certain genes and traits occurring within a population, as those organisms with favourable characteristics survive and pass on the genes to their offspring. Table 5.10 lists the steps involved in natural selection and gives as an example the effects on a population of beetles. The effects of natural selection on the numbers of red and green beetles in the population over time are set out in Table 5.11.

Table 5.10: The five steps of natural selection

Step	Example
1 There is variation within a population.	A population of beetles includes both red and green beetles.
2 A selection pressure in the ecosystem causes one trait to become favourable for the population of organisms.	Bushes that the beetles shelter in lose their red flowers and retain their green leaves.
3 The selection pressure increases the survivability of some of the population, because their traits are favourable.	Green beetles can still camouflage in the bushes.
4 External factors reduce the number of organisms with the non-favourable trait.	Predation from birds reduces the number of red beetles because they are easier to see and prey on.
5 The surviving organisms reproduce, passing on the genes that produce the favourable trait, meaning that over time it becomes the dominant trait in the ecosystem.	The green beetles become more prevalent over generations.

Table 5.11: The change in the numbers of red and green beetles when the environment favours the green beetles

Time (days)	Number of red beetles	Number of green beetles
0	22	22
2	19	26
4	13	31
6	9	34
8	6	39
10	3	42

This process of natural selection happens for all organisms across ecosystems. When populations of the same species become isolated, they can be exposed to different selection pressures, causing independent changes. This will be discussed further in Section 5.15 on evolution.

Figure 5.48: A red beetle on a green leaf is more visible than a green beetle on a green leaf so is more vulnerable to predation.

Figure 5.49: Scientists can test antibiotics to see if bacteria are resistant to them. Paper discs containing antibiotics are added to an agar plate. If an antibiotic kills the bacteria or prevents them from growing, there will be a clear zone around the antibiotic disc. If the bacteria are resistant, there will be no clear zone around the antibiotic because the bacteria have grown there.

Antibiotic resistance is an example of natural selection

The overuse of antibiotics has resulted in bacteria having increased resistance to antibiotics – this is an example of natural selection. The resistant bacteria have more chance of surviving and reproducing, and so antibiotic resistance increases throughout bacterial populations. Scientists are in a constant battle to stay one step ahead of the bacteria, synthesising new antibiotics – even though these can become ineffective very quickly.

Learning Ladder

Genetics and evolutionary change

1. Identify the five steps of natural selection.
2. Describe how selection pressures can influence which organisms survive in an ecosystem.
3. Explain how the colour of an organism can affect its survivability in an ecosystem.
4. Discuss natural selection, using an example from this section.
5. Evaluate how different processes can lead to variation within species.

Processing data and information

see page 412

Consider the information in Table 5.11.

1. Propose a reason for the change in the beetle populations.
2. Construct an appropriate graph representing the data from the table.
3. Calculate the average daily reduction of the red beetle population. Use the numeracy section of Science how-to (pages 446–62) to help you if needed.
4. 'The green beetles will always have superior genetics.' Use the data from the table and information from this section to support or refute this statement.
5. Propose one way to improve the information in the table to improve the conclusions that can be drawn from it.

In context

Many species provide evidence of natural selection in the environment. Conduct research into another species and explain how changes to its physical characteristics may have been a result of natural selection. Identify and describe the selection pressures responsible for the changes you explain.

Success criteria

- I can describe the process of natural selection.
- I can explain how natural selection causes change within and between populations.

5.13 ▸ Diversification of life

Learning intention

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

- explain how life has diversified over time
- explain how scientists use evidence from different sources to support the idea of evolution.

Key terms

absolute dating: determining the age range of an object, such as a fossil, in numbers of years

biogeography: the study of the past and present distribution of living organisms

common ancestor: an ancestor that is shared by two or more independent species

comparative anatomy: the study of similar anatomical structures in different species in order to understand their evolution

comparative embryology: the study of the similarity of the embryos of different species as they develop

evolution: the way in which organisms change over generations as a result of adaptations that suit their environment

fossil: the geologically altered remains of a previously living organism

fossil record: a record of all fossils that are on Earth

homologous structures: features in different organisms that are similar in structure, but different in function

relative dating: arranging geological objects and rocks in a sequence from oldest to youngest

vestigial structure: a feature of an organism that has lost some or all of its function through evolution

Investigation 5.13A

Dating fossils, page 535

Investigation 5.13B

Comparative anatomy, page 536

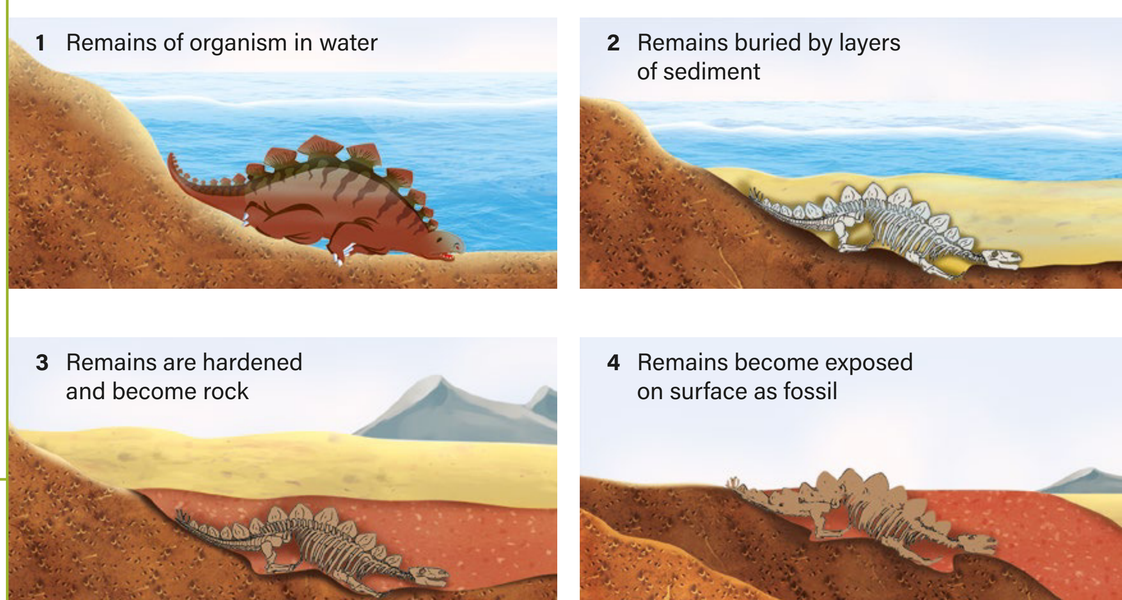
Content group: The theory of evolution and evidence of natural selection

One of the closest relatives to humans is thought to be the bonobo, a great ape that lives in regions of the Congo in Africa. Bonobos live to about 40 years of age and communicate vocally and through facial expressions. Scientists have used different kinds of evidence to make this conclusion. Similarities between their structures, genetics and distribution provide evidence that many organisms have a common ancestor and show how life on Earth has diversified over time.

Life on Earth started as single cells

Scientists are still investigating to determine exactly when and where life on Earth started. Current information suggests that the earliest life forms came into existence about 3.7–3.9 billion years ago, but new discoveries may indicate that it was even earlier than that.

The earliest known life forms were very simple cells in the ocean. Earth's atmosphere had not yet formed, so life could not exist on land. Over time, these organisms expanded across the ocean and gradually became more complex. Structures made of more than one cell emerged, and organisms eventually made their way onto land. This diversification continued and is the reason for all the variety we see today.



▲ **Figure 5.50:** Fossils form over millions of years, usually in sedimentary rock.

Figure 5.51: Fossils form when layers of sediment cover an organism. After millions of years, the organism can become an impression in solid rock.

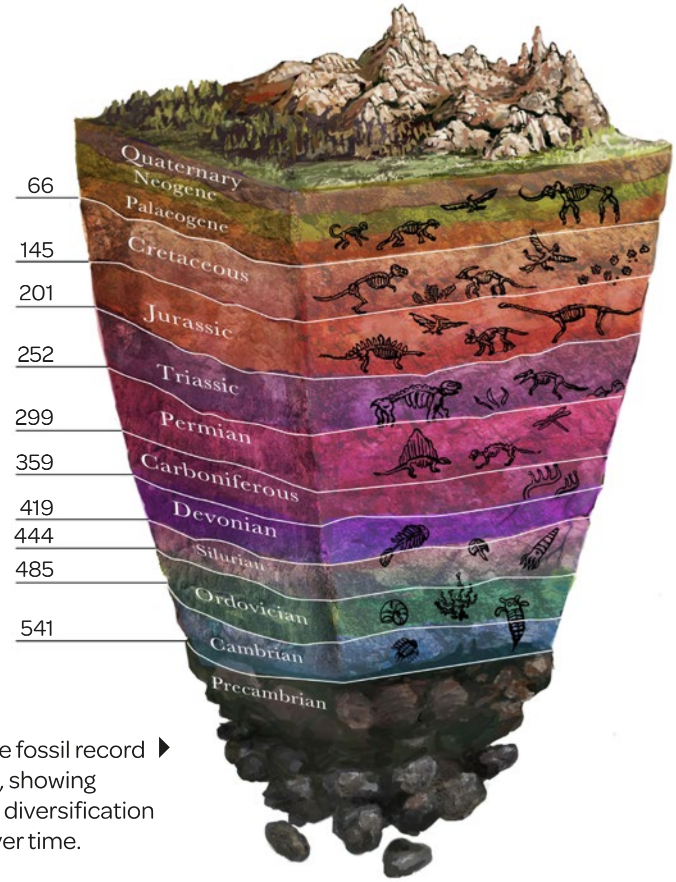


Figure 5.52: The fossil record arranges fossils, showing evidence of the diversification of organisms over time.

Fossils form over millions of years

Fossils are the remains, impressions or traces of long-dead organisms formed in rock and kept safe by geological processes. Fossils can be preserved bones or other remnants, shells, footprints, nests or eggs. Fossils are rare because they form only under certain conditions: the temperature, amount of oxygen and even soil acidity must be just right.

For fossils to form in rock, the following steps must occur over time:

- The organism dies, and its remains settle somewhere they will remain undisturbed (e.g. under water). The soft parts of the organism decay, leaving behind structures such as bones and teeth.
- The organism is covered with layers of sediment over time, which harden around it into rock.
- The skeleton dissolves and leaves a cast that is filled with minerals.
- The minerals crystallise and take the form of the mould left by the organism.

Fossils of complete organisms are also found in amber, which is hardened tree sap that encases small organisms or parts of organisms such as mosquitoes and leaves.

The fossil record provides evidence of evolution

Palaeontologists study the **fossil record**, which provides evidence of **evolution**. It shows how organisms have changed through geologic time from the simplest single-cell organisms to human beings. Although fossils have been found and dated from all around the world, many species are missing from the record, or their fossils have not yet been discovered. The gaps in the fossil record make it difficult to get an exact picture of all life forms. Also, it is hard to know whether a particular fossil is a good representation of a species.

Scientists date fossils in two main ways: relative and absolute dating. **Relative dating** gives an approximate age of a fossil by comparing it to other fossils or by studying the layers and ages of the surrounding stone. **Absolute dating** is commonly done by studying the radioactive minerals in the rock. Scientists can calculate the age of rocks by investigating how much the radioactive elements in them have decayed. Older fossils are of simpler organisms than younger fossils. This evidence supports the idea that life has diversified over time, because it suggests that much more complex organisms evolved from simpler ones.

Biogeography provides evidence of evolution

Biogeography is the study of the past and present distribution of living organisms. By studying where plants and animals are or were on islands and continents, scientists can start to piece together a complex and ancient puzzle.

Much of the evidence for biogeography comes from fossils. If fossils of one species are found in two separate continents, then this is compelling evidence that they were once connected. Australia has been an isolated island for many millions of years, which is why Australian marsupials and mammals are unique. However, even after Australia has been separated from the South American continent for millions of years, Australian marsupials still have some features in common with those in South America. This means that they probably evolved from a **common ancestor** millions of years ago. The wildlife in South America and Africa share more features than the wildlife in Australia and South America because that land separation happened later.

Common features provide evidence of common ancestors

Evolution is a gradual change in the physical characteristics of organisms over many generations. The first definite clues of evolution came by comparing the anatomy (especially the bones) of species to find similarities and differences. Scientists using **comparative anatomy** have found evidence to show that different species have evolved from the same ancestor. Parts of the body in different species that show evidence of common features are called **homologous structures**.

Vestigial structures are another type of evidence. These are parts of organisms that have lost their function as a species has evolved. They remain in the organism, sometimes even causing problems. Vestigial structures in humans include wisdom teeth, the appendix, the tailbone, and nipples on men.

Figure 5.53: Comparative embryology shows the similarity between organisms early in their development.

Comparative embryology is another piece of evidence that supports evolution and the diversification of life over time. Scientists examine the developing embryos of different species to compare what they look like at different stages of development. Early in development, it is nearly impossible to see the difference between a human, bird, turtle and rabbit embryo. This similarity is further evidence that organisms have a common ancestor.

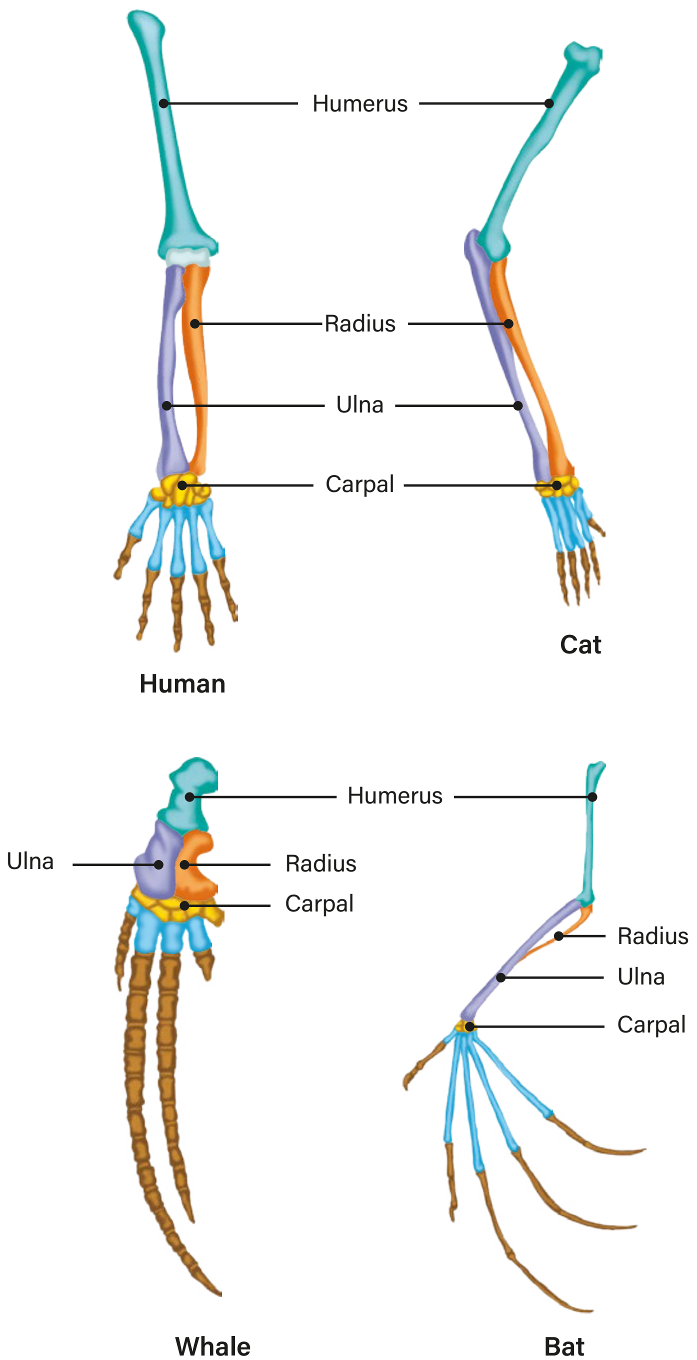


Figure 5.54: The human arm, cat leg, whale fin and bat wing are homologous structures that show evidence of a common ancestor.

Genetic evidence shows how closely species are related

From 1990 to 2003, teams of scientists all over the world worked together to completely map the DNA of humans in a huge endeavour called the Human Genome Project. Now we can compare the DNA of different species and identify how similar they are. DNA mapping shows that humans and bonobo great apes share many genes, providing evidence that we had a common ancestor.

Learning Ladder

Genetics and evolutionary change

1. Identify three factors that can provide evidence of the diversification of life on Earth.
2. Describe how each of the factors you identified in Question 1 provides evidence of diversification.
3. Explain how genetic evidence shows the relationship between different species.
4. Discuss the reason that multiple pieces of evidence should be included when looking at the diversification and evolution of life.
5. Evaluate how strongly each piece of evidence in this section supports the idea of evolution.

Processing data and information *see page 412*

1. Consider the embryos in Figure 5.53. Identify the point where you can begin to distinguish between organisms of different species and propose why this supports the concept of species and organisms sharing a common ancestor.
2. Construct a table from Figure 5.52 that compares the time periods on Earth to organisms that existed in them.
3. Calculate the amount of time, in millions of years, between the Triassic and Pliocene periods.

In context

Single-celled organisms have existed for billions of years. One specific example of an early organism is LUCA (the last universal common ancestor). Conduct research into LUCA and explain the significance of this discovery in relation to the diversification of life on Earth.

Success criteria

- I can explain how scientific evidence supports the idea that life on Earth has diversified over time.

5·14 ▶ Aboriginal and Torres Strait Islander Peoples' artwork indicates changes in plants and animals, including megafauna

Learning intention

At the end of this lesson, I will be able to understand how First Nations rock art provides important scientific knowledge of changes in plants and animals over many tens of thousands of years.

Key terms

Gondwanaland: the supercontinent that broke from Pangaea approximately 250 million years ago and was made up of the modern-day continents of Africa, South America, Australia and Antarctica

megapode: a class of flightless bird that had large legs and feet and built nesting mounds in which to lay its eggs

Dreaming Stories: complex First Nations stories that hold significant knowledge about history, creation, law, lore, and many other knowledges; have been used by First Nations Peoples for tens of thousands of years to care for Country and to live well

Content group: The theory of evolution and evidence of natural selection

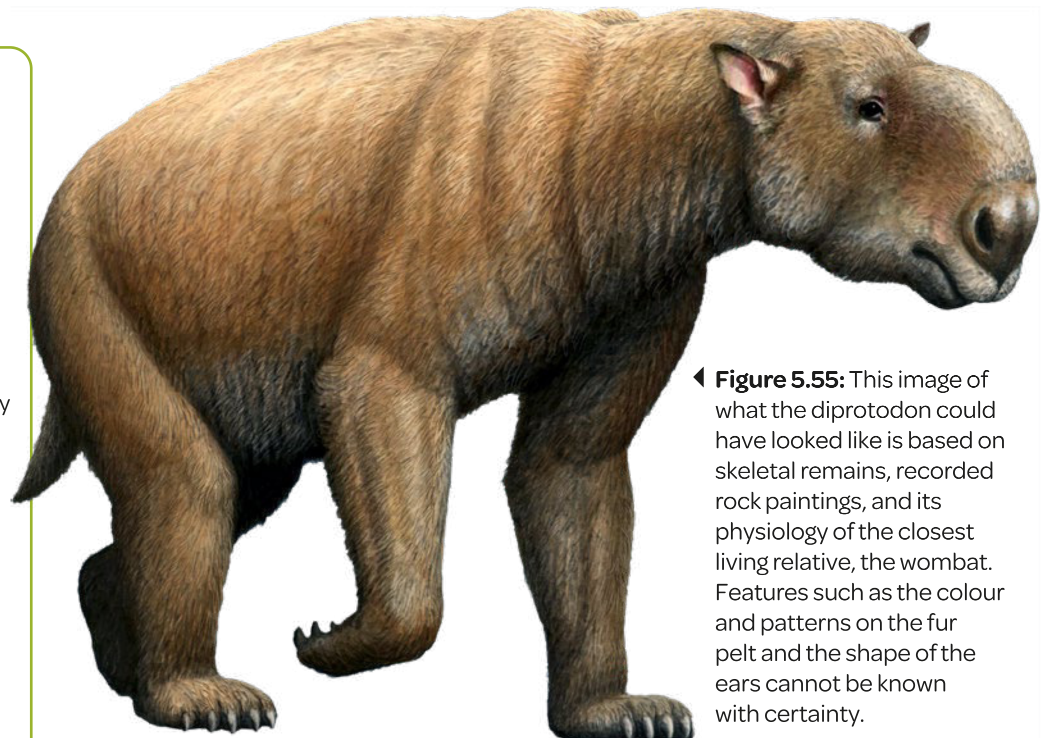


Figure 5.55: This image of what the diprotodon could have looked like is based on skeletal remains, recorded rock paintings, and its physiology of the closest living relative, the wombat. Features such as the colour and patterns on the fur pelt and the shape of the ears cannot be known with certainty.

Continental drift – the splitting of the continents from **Gondwanaland** 250 million years ago – created the conditions and the time required for unique species of plants and animals to evolve on the Australian continent and adjacent islands. This meant that when the first humans arrived, there were many unique species of plants and animals in the environment.

First Nations Peoples hunted megafauna

On the eve of colonisation in 1788, First Nations Peoples had been in Australia for at least 65 000 years. During that time, they had coexisted with many now-extinct animals. There is a growing body of evidence that First Nations Peoples hunted and killed different types of megafauna, including *Diprotodon optatum*, a rhino-sized marsupial wombat, and *Genyornis newtoni*, a giant ground-nesting bird. The **megapode** was a flightless bird that reached more than 2 metres in height. Remains of these animals have been found in the Warratyi Rock Shelter in the Flinders Ranges in South Australia.

The Warratyi Rock Shelter is considered to be one of the oldest inhabited places in the Australian arid interior. It had year-round abundant freshwater springs and ample edible plants for gathering and animals to hunt, including the megafauna.

Images of ancient megafauna

Dreaming Stories and rock-art images refer to animals that are now extinct on the Australian continent and the adjacent islands. It was once thought that hunting by First Nations Peoples caused the extinction of the megafauna. However, evidence now indicates that a sharp fall in the numbers of megafauna coincided with the last Ice Age, when the drying out of the continent impacted their plant-based food sources.

Some First Nations rock art shows what the extinct megafauna may have looked like. One example is the *Thylacoleo carnifex*, also known as the marsupial lion. This animal lived in forested areas across the Australian continent until its extinction 35 000 years ago. Palaeontologists have excavated several skeletons of the marsupial lion, but it is the rock art that provides insights into the shapes and patterns on the pelt of this animal and the shape of its ears – both parts of the animal that have not been preserved. Interestingly, the climate where these paintings are located has changed significantly, and the rock art suggests what the climate may have been like many thousands of years ago.

Figure 5.56: A rock art painting of a human figure throwing a spear at what is thought to be a *Thylacoleo carnifex* (marsupial lion) estimated to have been created from 15 000 to 22 000 years ago in Western Australia. The fossil remains of the lion tell us very little about the colour and the pattern of the fur pelt (note the stripes in the image); however, this image provides important insights into the appearance of this extinct species. The Drysdale River painting may be the first direct evidence of an interaction between a human and a now-extinct animal in ancient Australia.

Ancient plants are depicted in rock art

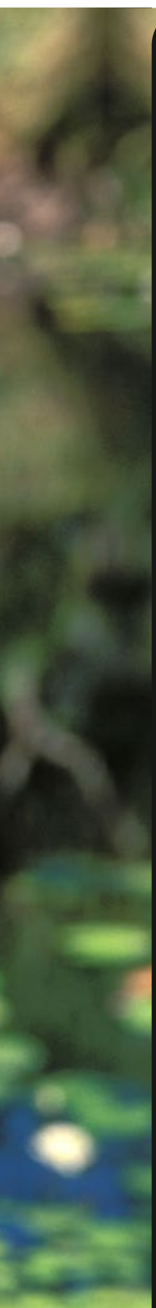
There are many rock art sites in the Kimberley region in Western Australia where various plants are depicted. In many cases, the plants are painted in their unprocessed forms and as objects, tools and other items, or as foods. The images are depicted in different styles of art, as listed in Table 5.11.

The various styles show different plants from the local landscape, and their uses, changing patterns of growth and availability, over many tens of thousands of years. These images also provide an important understanding of how the climate and sea-level changes affected the ability of the plants to survive and thrive in the changing landscapes.

Figure 5.57: Water lilies, plum and long yam were common edible plants when the rock paintings were created. First Nations Peoples continue to use these plants today.

Table 5.12: The different styles of art represented at the Kimberley rock art sites

Style	Date	Description
Pecked Cupule	50 000 years ago	Known for its mosaics of rainforest, woodland and grasslands, which reflects the local climate at that time
Irregular Infill Animal	36 000–18 000 years ago	Indicates an increasing aridity in the local landscape
Gwion	18 000–14 000 years ago	Indicates significant changes to sea levels relating to the last glacial maximum of the most recent Ice Age
Static Polychrome	14 000–9000 years ago	Relates to when the monsoon seasonal weather pattern was re-established after the Ice Age and to the loss of coastal plain due to rising sea levels
Painted Hand	9000–5000 years ago	Coincides with the Holocene wet period and the resulting increase in the human population as a result of the environment becoming wetter and better able to sustain a larger population
Wanjina	5000 years ago to present day	Marked by greater volatility in summer rainfall and periods of drought



Learning Ladder

Genetics and evolutionary change

1. Identify a characteristic or trait that the marsupial lion, the diprotodon and *Genyornis newtoni* shared that would have contributed to their extinction.
2. Examine Figure 5.55 and describe the traits shown in the image that would have been transmitted through generations of marsupial lions.
3. Explore the images of the native plants in Figure 5.57.
   - **a** Identify a desirable characteristic.
   - **b** Explain how First Nations farmers could have improved this characteristic.
4. Identify a trait of the diprotodon that contemporary wombats do not have. Discuss how this has ensured that contemporary wombats could survive the increased aridity in the landscape.
5. Evaluate how the art styles in the Kimberley, listed in Table 5.12, support natural selection as a process that influences evolution.

Communicating

see page 429

1. Consider Figure 5.55. Identify the parts of the image that can be determined from the skeletal remains. Describe the parts of the image that have been informed by First Nations rock paintings and observations of the animal's nearest living relatives.
2. Describe how images of animals were depicted in the rock art painted by First Nations Peoples. Digitally list some of the advantages of recording the animals for the people learning about them.
3. Examine the different plants in Figure 5.57.
   - **a** Construct a presentation about each of the plants, detailing what each is used for.
   - **b** Label each image to identify the various parts of the plant.
   - **c** Identify the edible parts of the plant and describe how these were prepared for consumption.
   - **d** Conduct research and discuss where these plants can be found today.
4. Explain what advantages painting the edible parts of plants would have provided First Nations Peoples.

In context

Another extinct Australian native species is the thylacine (Tasmanian tiger). While European colonists only recorded the tiger inhabiting Tasmania, evidence of thylacines has been found in rock paintings by Yolngu People in far north Australia. Propose reasons for the change in tiger distribution and explain how these paintings provide evidence of change in organisms.

Success criteria

- I can describe how ancient rock art can provide important scientific knowledge from the past.
- I can explain how recording images can be an effective way of learning about the plants and animals in the environment.

5.15 ▸ The theory of evolution by natural selection

Learning intention

At the end of this lesson, I will be able to discuss the theory of evolution by natural selection and explain how it is supported by evidence.

Key term

theory of evolution by natural selection: a theory that says species have evolved adaptations over time that helped them to survive in their environment

Content group: The theory of evolution and evidence of natural selection

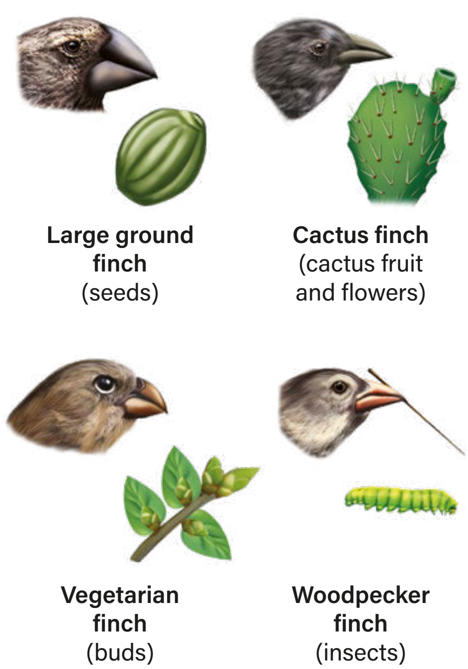


Figure 5.58: The finches of the Galapagos Islands evolved different beaks in response to the food sources available to them.

Living things have diversified since life began on Earth. How do scientists explain this?

Evolution is caused by natural selection

The diversification of life is a result of natural selection. Favourable characteristics are passed from parents to offspring and become more common over generations. As populations separate and are exposed to different conditions, specific traits can become favourable, causing changes between the populations, which eventually become different enough to be seen as two distinct species. The gradual change over many generations is called evolution.

Darwin and Wallace developed the theory of evolution

Charles Darwin and Alfred Wallace studied the diversity of life. Throughout the 1800s, they independently travelled to different parts of the world, making observations about living things and collecting evidence. The two scientists separately came up with the idea that species evolved by passing down genetics for adaptations that helped them to survive in their environment. In 1858, they published a paper together outlining the **theory of evolution by natural selection**. Darwin, who also published a book called *On the Origin of Species*, is much more commonly associated than Wallace with the theory of evolution by natural selection.

Galapagos animals helped Darwin develop the theory of evolution

In 1831, Darwin set sail from England on a five-year expedition. On his journey, he found enormous fossils and many species of animals that forced him to consider new theories for the origins of life on Earth. He also discovered several species of finches on the Galapagos Islands, off the coast of Ecuador.

The finches looked very similar, but their beaks were different lengths and shapes. Darwin theorised that the finches had a common ancestor, but after they separated geographically to different islands and had different food sources, they evolved different beaks through natural selection (Figure 5.58).

Darwin also studied the Galapagos tortoise. He observed that the environment and available food supply affected the tortoise's shell shape (Figure 5.59).


Figure 5.59: The shell shape of the Galapagos tortoise is linked to its evolution. Saddle-shaped shells (left) with a gap at the front help tortoises with a limited food supply to reach food from higher sources, such as cacti, while lower dome-shaped shells (right) are prevalent where the tortoises have a large supply of lush, low-lying vegetation.

Many scientists have contributed ideas on evolution

Before Darwin and Wallace, many scientists contributed to our understanding of evolution. Jean-Baptiste Lamarck suggested that animals adapt to their surroundings. However, unlike Darwin, Lamarck suggested that this adaptation occurred during the life of the animal, rather than adaptations being inherited from parents.

Many scientists have since contributed to our further understanding of evolution. The study of fossils and how to date them, DNA and genetics, and mapping the genome of humans and other animals have all built on the work of Darwin and Wallace. Today, many different processes are used to provide supporting evidence for the theory of evolution by natural selection.

Learning Ladder

Genetics and evolutionary change

1. Identify three scientists who contributed ideas to our understanding of how organisms change over time.
2. Describe how Darwin and Wallace were able to come up with similar ideas about evolution at about the same time.
3. Explain how the organisms of the Galapagos Islands provided Darwin with evidence that supported the theory of evolution by natural selection.
4. Discuss how the characteristics of different organisms can provide evidence of evolutionary change.
5. Evaluate how the theory of evolution by natural selection accounts for the change in diversity of life over time.

Communicating

see page 429

1. Propose an appropriate way to communicate the key ideas of the theory of evolution by natural selection.
2. Construct a digital timeline of Lamarck, Darwin, Wallace and modern scientists that you have learnt about in this section, outlining the evidence they have provided that has increased our understanding of the theory of evolution by natural selection.
3. Use your answer from Question 1 to construct a presentation explaining the theory of evolution by natural selection.
4. Alter your presentation so you could present it to a group of parents who were visiting your school.
5. Using the information from this section and secondary-sourced research, evaluate the validity of the theory of evolution by natural selection.

In context

Wallace also visited many places and observed organisms while collecting his ideas about evolution. Conduct research to identify three organisms Wallace observed, and explain how they also provided supporting evidence for the theory of evolution by natural selection.

Success criteria

- I can explain the theory of evolution by natural selection.
- I can discuss how specific evidence supports the theory of evolution by natural selection.

5·16 ▸ Genetics and evolutionary change in context

Learning intention

At the end of this lesson, I will be able to construct an evidence-based argument on the use of a genetic technology.

Key terms

genetic technology: a technology used by scientists to study or alter living things

stem cell: an undifferentiated cell

Content group: Genetics and evolutionary change in context

Genetic technologies are used by scientists for many different purposes. Some technologies alter crops and organisms to optimise yields; others are used to help with research into areas such as medicine and disease. But should we always use effective genetic technologies, regardless of the cost?

HeLa cells are a genetic technology

In 1951, Henrietta Lacks (Figure 5.60) was a patient being treated for cervical cancer at Johns Hopkins Hospital in Maryland, in the United States. Throughout the course of her treatment, a sample of cancer cells was taken to be examined. Lacks died within 12 months of starting treatment. She was 31 years old.

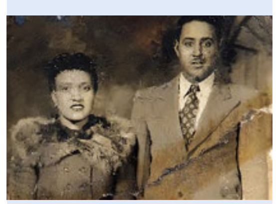
Lacks's **stem cells** were used for research without her knowledge or approval. Scientists studying the cells discovered something amazing. The cells that carried cancerous mutations were able to continually divide and survive in laboratory conditions, outside of the human body. Scientists labelled these cells 'immortal cells' because they continued to grow and divide. They were named HeLa cells, in honour of the woman they came from, and were subsequently distributed to many research facilities for use in various tests.

1920

Henrietta Lacks was born Loretta Pleasant on 1 August 1920, in Roanoke, Virginia, to Eliza and Johnny Pleasant.

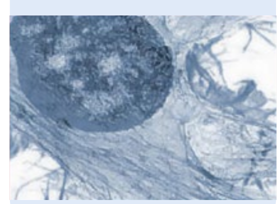
1941

On 10 April 1941, Henrietta Pleasant married David 'Day' Lacks.



1951

A biopsy of Henrietta Lacks's tumour was taken and sent to the lab of Dr George Gey, resulting in the creation of the HeLa cell line.



1952

Scientists used HeLa cells to help develop the polio vaccine.

Figure 5.60: Henrietta Lacks was just 31 years old when she died of cervical cancer while seeking treatment at Johns Hopkins Hospital.

The use of HeLa cells has led to many scientific discoveries

Since the distribution of HeLa cells began in 1952, there have been more than 110 000 scientific papers published on studies that have used the HeLa cell line to conduct research. Some key findings are listed below and are shown in Figure 5.62.

- **1953**: Scientists studying the polio virus found that the HeLa cells could withstand large amounts of the virus replicating within them, which meant that larger quantities of the virus could be studied. This provided a framework for the development of the polio vaccine.
- **1956**: HeLa cells were used to study the effects of X-rays on human body cells and how they grow. They were also used to develop tests that are still used today to determine whether cells are cancerous.
- **1964**: HeLa cells were put on space shuttles, to study how humans are affected by space travel.
- **1985**: Scientists used HeLa cells to make a connection between human papillomavirus (HPV) and cervical cancer, helping with the development of the HPV vaccine. The cells were also involved in studies that helped to discover a drug to slow cancerous cell growth.
- **1993**: Scientists studied and discovered how tuberculosis makes people sick.
- **2001**: HeLa cells were used to develop new microscope imaging techniques that help to give scientists a clearer view of cell organelles and of how viruses enter cells.
- **2010**: Researchers used HeLa cells to show that the drug thalidomide could cause birth defects. They have subsequently focused their research on cancer and are developing methods for slowing, and even stopping, the growth of certain cancers.

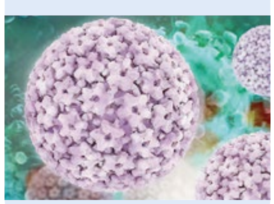
Figure 5.61: Development of the polio vaccine in the 1950s was made possible by research conducted using HeLa stem cells.

1973

Scientists used HeLa cells to study the behaviour of salmonella inside human cells.

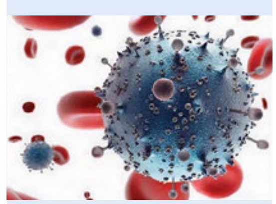
1984

HeLa cells were used by a German virologist to help prove that the human papillomavirus (HPV) causes cancer.



1986

The virus infection mechanism of HIV was studied by scientists who infected HeLa cells with HIV.



1993

HeLa cells were used to study tuberculosis.

2013

The US National Institutes of Health (NIH) announced an agreement with the family of Henrietta Lacks to allow biomedical researchers controlled access to the whole genome data of HeLa cells.

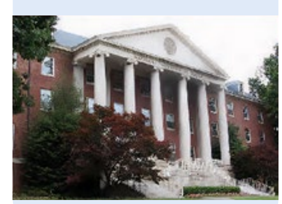


Figure 5.62: A timeline of some of the key findings made possible by HeLa cells

The use of HeLa cells has ethical implications

Although HeLa cells have provided invaluable contributions to our understanding of many diseases and medical practices, there are ethical considerations that need to be addressed. Henrietta Lacks was never told that her cells were going to be used for research, so she was never provided an opportunity to give consent for their use.

The Nuremberg Code (1947) relates to medical experimentation on human subjects. While the Code is related to experiments on living subjects, rather than on the cells of patients, the first standard of the Code states: 'The voluntary consent of the human subject is absolutely essential.' Henrietta Lacks was never experimented on, but the line of HeLa cells has been used in thousands of studies. Should this have been done without her consent?

Figure 5.63: The Nuremberg Code is a set of ethical principles for research involving humans. It arose out of war trials following the Second World War and includes the right to be informed, voluntary consent, and rules about the use of genetic material in testing.

▲ **Figure 5.64:** Fluorescence microscopy has allowed us to view HeLa cells and their genetic material.

Another aspect to consider is privacy around Lacks's medical history. The Declaration of Helsinki, which was adopted by the World Medical Association in 1964, states: 'It is the duty of physicians who are involved in medical research to protect the life, health, dignity, integrity, right to self-determination, privacy, and confidentiality of personal information of research subjects.' Given that Henrietta Lacks's privacy was not maintained, and that her family was not offered the opportunity to give consent on her behalf for the continued use of the HeLa cell line, should worldwide research using the cells have continued?

The continued use of HeLa cells must be carefully considered

Today, HeLa cells can still be used. Lacks's descendants filed a lawsuit against a biotechnology company that used HeLa cells to profit from the development of new medical treatments. Despite this, Lacks's descendants are leading a campaign, #HELA100, that aims to support knowledge of Lacks's life and legacy, and of the contributions her cells have made to scientific discovery. The campaign promotes the idea that, if HeLa cells are used correctly, with acknowledgement, and not for private profit, they should continue to be accessible by scientists to drive medical developments that will benefit us all.

Learning Ladder

Genetics and evolutionary change

1. Identify three uses of HeLa cells that contributed to the development of medicines.
2. Describe the significance of HeLa cells in a laboratory.
3. Explain why there has been controversy around the use of HeLa cells.
4. Discuss why specific documents like the Nuremberg Code and the Declaration of Helsinki are important for medical research.
5. CRISPR is a genetic technology that allows scientists to modify the DNA of living organisms. Conduct research into CRISPR to explain how it works, and construct an argument evaluating its uses, including any ethical considerations.

Communicating

see page 429

1. Describe an appropriate way to communicate information about Henrietta Lacks and the contribution of HeLa cells to scientific research.
2. Construct an infographic that relates to the information you described in Question 1.
3. Use the timeline and information in this section to construct a scientific poster that shows the key scientific findings that can be attributed to HeLa cells.
4. Explain how you could present your poster to a committee of scientists who were looking into research on diseases.
5. Evaluate the significance of genetic technologies for increasing our understanding of diseases.

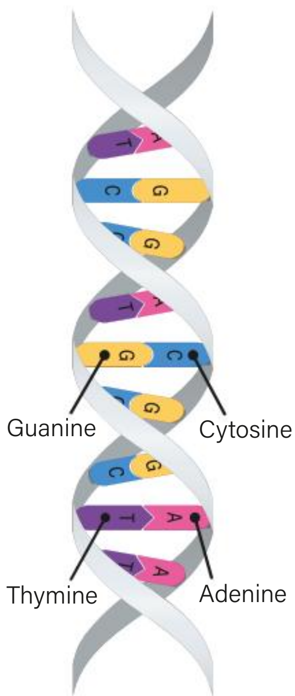
Success criteria

- I can identify a specific use of a genetic technology.
- I can construct an argument that considers the ethics and implications of using that genetic technology.

Genetics and evolutionary change summary

DNA structure and function

- All living things require genetic material. Genes are condensed and stored as chromosomes on DNA.



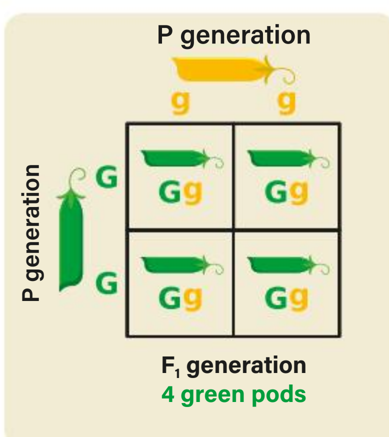
- Humans contain 46 chromosomes, arranged in 23 pairs.
- DNA is held together by chemical bonds. Its double helix structure enables it to separate for replication and allows cell division to occur.
- Nucleotides on DNA are used to construct proteins, which allow organisms to carry out everyday functions.
- Scientists Franklin, Wilkins, Watson and Crick all made key contributions to our understanding of the double helix structure of DNA.

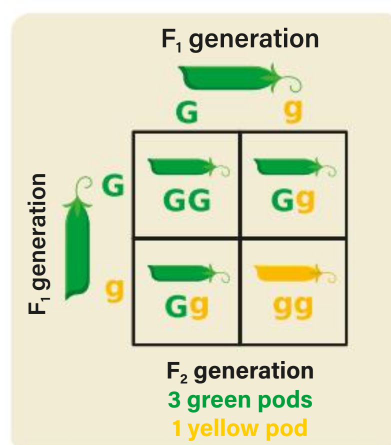
Variation and inheritance

- Reproduction can be sexual (two parents provide gametes that fuse to create a unique offspring) or asexual (one parent creates an identical copy of itself).
- Cells need to divide for reproduction to occur. Mitosis (asexual) produces identical diploid cells. Meiosis (sexual) produces unique, haploid cells.

Type of organism	Type of reproduction	Example organism
Animal	Both	Sexual – mammals (e.g. humans, zebras)
		Asexual – sea stars
Plant	Both	Sexual – roses
		Asexual – potatoes
Bacteria	Asexual	*Escherichia coli* – bacteria
Fungus	Both	Sexual – mushrooms
		Asexual – yeast
Protist	Asexual	Amoebas

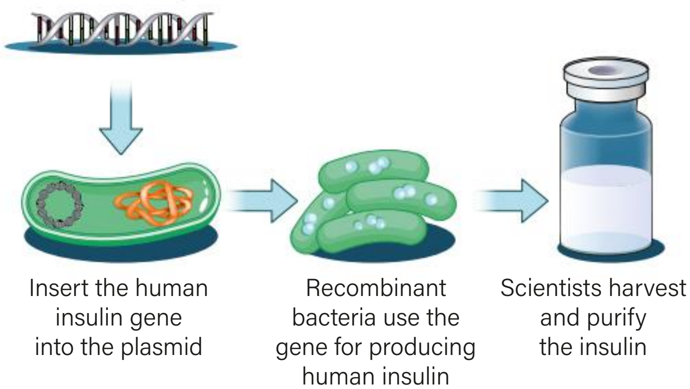
- Human reproduction is sexual and involves the fusing of ova and sperm to create a zygote.
- Physical traits are influenced by our genetics and by environmental factors such as exposure to sunlight and intake of nutrients.
- Mutations are changes to the nucleotides of DNA. They are caused by many different factors and can be beneficial (lactose tolerance), harmful (cystic fibrosis) or have no impact (silent).
- Mendelian inheritance allows us to connect genotypes and phenotypes for monogenic traits. Recessive traits are typically expressed in 1 in 4 offspring.
- Punnett squares can be used to determine the possible genotypes and phenotypes of a single generation of offspring.
- Pedigrees can be constructed to track the expression of specific genetic traits across multiple generations and family members.





Genetic technologies

- Genetic technologies deliberately alter the genetics of an organism, through processes such as cloning and gene therapy.
- Genetic technologies can be used in many areas, such as conservation (Tasmanian devil populations), agriculture (BT cotton), industry (mining) and medicine (insulin production).
- Genetic testing can be used to screen for different conditions, and has many social, economic and ethical considerations. For example: Who has access to these technologies? Who gets to choose which technologies to implement and which to exclude?



The theory of evolution and evidence of natural selection

- Natural selection is the process by which selection pressures such as isolation cause changes to a population of organisms across generations.
- Variation in populations can occur during meiosis, fertilisation and as a result of mutations that are inherited.
- Organisms have diversified significantly, and become increasingly complex, since life on Earth started, evolving from single-celled organisms to all of the plants, animals and microorganisms that exist today.
- Fossils provide evidence of the diversification of life over time.
- Rock paintings by ancient Aboriginal and Torres Strait Islander Peoples of organisms such as the diprotodon show how Australia's life forms have changed.
- Many scientists contributed ideas about evolution. However, Darwin's theory of evolution by natural selection is the currently accepted scientific theory explaining the evolution of species.
- Evidence for evolution includes the finches of the Galapagos Islands, biogeography, comparative anatomy and comparative embryology.

Genetics and evolutionary change in context

- The use of genetic technologies such as the HeLa stem cell line, which came from the cells of Henrietta Lacks in the early 1950s, must be carefully considered to ensure strict adherence to frameworks of ethics, such the Nuremberg Code and the Declaration of Helsinki.

Masterclass

Steps in progression

		1	2
Content	Genetics and evolutionary change	Identify two characteristics of the snail species present on the Galapagos Islands that have evolved over time.	Describe how the shells of the snails of the Galapagos Islands differ from those you might find in your garden.
Processes	Processing data and information	Identify the number of snail species present on the Galapagos Islands.	There are many different organisms in addition to snails on the Galapagos Islands. They include: • 15 subspecies of Galapagos tortoises • 13 finch species • 6 gecko species • 4 iguana species. Construct a graphical representation comparing the number of different species for each organism.
	Communicating	Propose an appropriate way to present information visually on the diversity of the species of snails that inhabit the Galapagos Islands.	Consider your representation from step 2 of the 'processing' ladder. Use a spreadsheet to present this as an appropriate digital table and graph.

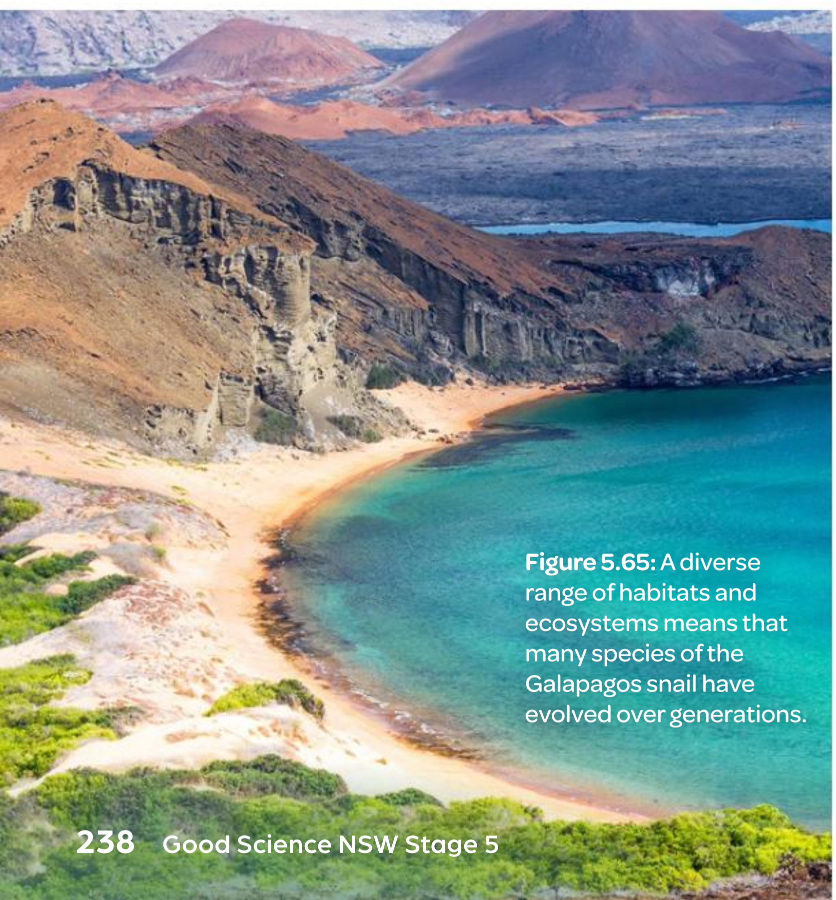


Figure 5.65: A diverse range of habitats and ecosystems means that many species of the Galapagos snail have evolved over generations.

The Galapagos Islands host more than just tortoises and finches

Charles Darwin's research focused on tortoises and finches. However, the Galapagos Islands contain many diverse species, including its snails. While small, land snails have spread across multiple islands and taken up residence in many different ecosystems. Over 100 distinct snail species have been found on the Galapagos Islands, inhabiting a variety of habits – from lush forests to damp caves to arid volcanic rocks. The snails have distinct shell lengths, colours and patterns that have evolved over generations as snails in each area passed on these favourable genetics to their offspring. Over time, this has led to the diverse range of snail species found in the Galapagos Islands today.

Demonstrate your understanding

3	4	5	
Explain what you might expect to find in the genetics of the snails that would cause the difference in shell shape.	Discuss how the colours of the snails' shells could be used to provide supporting evidence of evolution, given the different ecosystems they inhabit.	Evaluate the use of the snails of the Galapagos Islands as evidence for the theory of evolution by natural selection.	
Use secondary-sourced information (such as from the Galapagos Conservation Trust website) to analyse the diversity of species on the Galapagos Islands. Propose four reasons for this diversity.	Use the provided information on the land snails of the Galapagos Islands, as well as secondary research, to support or refute the statement: 'No single organism could exist as one species across all of the islands of the Galapagos.'	Evaluate the quality of your secondary-sourced investigation in steps 3 and 4, based on the online sources that you accessed. (Hint: Use the Science how-to section on pages 441–43 to help you evaluate your sources of information.)	Science how-to p. 412
Construct your suggested presentation from step 1 using a digital platform of your choice. Include information on snail shell types, colouring and habitats, and link these factors to the evolution of the snails.	Assess your presentation as a way to inform Year 7 students about the theory of evolution by natural selection. Use your assessment to make changes to your presentation as needed, so that it is suitable to present.	Use the information from these pages, and from the secondary sources you have accessed, to evaluate Charles Darwin's findings and scientific conclusion: the theory of evolution by natural selection.	Science how-to p. 429



Figure 5.66: The shells of different Galapagos snail species vary in length and colouring, based on the environments the snails inhabit.

Focus area 6

6.0 Reactions

Reactions are powerful processes that transform matter in different ways. Chemical reactions involve the rearrangement of atoms to produce new substances, while nuclear reactions change the nucleus of an atom, releasing vast amounts of energy. Alongside these topics, you will also sharpen your technical investigation skills, allowing you to gain a clearer understanding of reactions and how they apply to the real world.

Learning Ladder

The Learning Ladder contains the scientific content and processes you will learn in this focus area. Each area has five levels of progression. To move to higher levels, you need to practise activities at the earlier levels. This will help you develop the ability to complete tasks that are more complex.

Steps in progression	Reactions	Observing	Questioning and predicting	Planning investigations	Conducting investigations	Steps in progression
5	I can analyse the real-world implications of reactions used in different industries.	I can select scientific equipment to improve the precision of my observations.	I can evaluate questions and hypotheses relating to scientific phenomena.	I can assess the type of data that can be collected in a range of investigations.	I can extract data from secondary sources and construct appropriate references to acknowledge their use.	5
4	I can apply my understanding of reactions to represent changes that take place.	I can use observations and measurements to answer questions.	I can formulate testable questions and predictions, considering variables and controls.	I can produce plans for investigations that are ethical, reliable and valid.	I can accurately collect and record data, information, evidence and findings from first-hand and second-hand investigations.	4
3	I can explain how different factors affect reactions.	I can make inferences based on my observations.	I can propose hypotheses based on scientific knowledge.	I can develop appropriate scientific aims for a range of investigations.	I can conduct first-hand investigations and accurately record the collected data and identify errors.	3
2	I can describe changes that occur in a range of reactions.	I can record observations and measurements accurately.	I can construct questions to investigate scientific concepts or problems.	I can distinguish between controlled, dependent and independent variables.	I can use scientific equipment to conduct investigations and gather first-hand data and information.	2
1	I can identify different types of reactions.	I can use scientific tools to enhance observations.	I can select questions to investigate scientific concepts or problems.	I can describe ways to reduce risks for a range of investigations.	I can implement safe practices when using scientific equipment.	1
	Content	Working scientifically processes				

Figure 6.1: This image contrasts the dynamic power of chemical reactions at the atomic level and nuclear reactions at the cosmic level.

6·1 ▸ The law of conservation of mass and chemical reactions

Learning intention

At the end of this lesson, I will be able to explain the law of conservation of mass.

Key terms

closed system: a system from which energy can flow in and out but matter cannot

conservation of mass: mass cannot be created or destroyed

electrolysis: passing electricity through a substance to break it up

molecular formula: a chemical formula for molecules showing the type and exact number of atoms in a substance

molecule: two or more atoms covalently bonded to form a discrete or separate unit of atoms

open system: a system that allows matter and energy to flow in and out

particle: a small part of a type of matter, including an atom or a molecule

product: a substance formed in a chemical reaction

reactant: a substance at the start of a chemical reaction

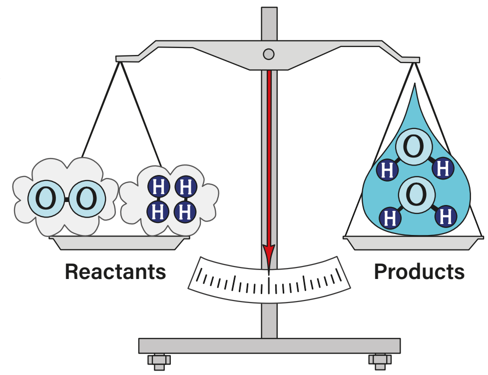
Investigation 6.1

Investigating the law of conservation of mass, page 537

Content group: Law of conservation of mass

An unbreakable law of the universe is that matter cannot be created or destroyed. The mass of the substances before a reaction is equal to the mass of the substances after the reaction. This law helps us to understand different types of chemical reactions.

Figure 6.2: A chemical reaction results in particles being rearranged, but the mass of the reactants is equal to the mass of the products; mass is conserved.



Mass is conserved in open and closed systems

Even when it appears that mass is lost in a reaction, it has just changed form or moved from one place to another. For example, the wood burning in a campfire is not disappearing; it is reacting with oxygen to form carbon dioxide and water vapour, which floats away into the atmosphere. This is an example of an **open system**, which allows matter to flow in and out.

We can observe first hand the law of **conservation of mass** when a reaction takes place in a **closed system**. Matter cannot enter or leave, so during a chemical reaction, substances may change form, but the total mass stays the same. All atoms involved in the reaction are accounted for, and the mass of the **reactants** equals the mass of the **products** (Figure 6.4).

Figure 6.3: A campfire is an example of a combustion reaction in an open system. The products – water, soot and carbon dioxide – escape into the atmosphere, making it seem as though the matter in the wood has disappeared.

Figure 6.4: When silver nitrate and copper wire are placed in a closed system, the copper replaces the silver in solution. It appears as though silver matter has been created around the copper wire, but the mass of the flask does not change.

Particles rearrange during a chemical change

The **particles** at the beginning of a chemical reaction are not the same as those at the end. In a reaction, the atoms in the reactants are rearranged to form particles of new substances. For example, water **molecules** (**molecular formula** H_2O) can be broken apart by **electrolysis**. The covalent O–H bonds break apart and the atoms rearrange to form hydrogen gas and oxygen gas.

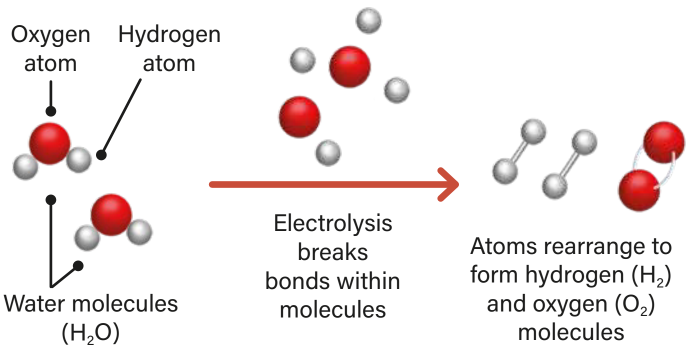


Figure 6.5: When water undergoes electrolysis, the original atoms are conserved and rearranged.

Chemical reactions conserve mass

Mass is always conserved in reactions. Table 6.1 describes how chemical reactions can be classified.

Table 6.1: Classifications of chemical reactions

Type of reaction	Description	Example
Combustion	A fuel reacts with oxygen to form carbon dioxide and water.	Wood burning in a campfire
Synthesis	More than one reactant combines to form a single product.	Iron rusting with oxygen to form iron oxide
Decomposition	One reactant breaks down into multiple products.	Water breaking down into hydrogen and oxygen
Displacement	A more reactive element replaces a less reactive one in a compound.	Copper metal replacing silver in solution to form silver metal
Neutralisation	An acid and a base react to form a neutral salt and water.	Hydrochloric acid and marble chips reacting to form calcium chloride salt, water and carbon dioxide

Learning Ladder

Reactions

1. Identify the two types of systems in which chemical changes can occur.
2. Total mass does not change in a chemical reaction. Describe what *does* change.
3. Explain how the law of conservation of mass is observed differently for reactions in open and closed systems.
4. Construct a word equation to represent the reaction taking place in Figure 6.4.

Observing

see page 398

Refer to Figure 6.4.

1. Identify the equipment used that improved the quality of the first-hand observations.
2. Copy and complete the following table.

	Silver nitrate + copper wire: Dot-point observations (qualitative and quantitative)
Flask before reaction took place	
Flask after reaction took place	

3. Describe inferences that can be made based on your observations recorded in Question 2.
4. Justify the following statement, with reference to your observations: 'Figure 6.4 demonstrates the law of conservation of mass.'
5. Propose additional equipment that could be used to collect more precise observations. Explain your answer.

In context

As pipes rust, large holes form, which indicates that the pipes will eventually disappear. Conduct an online search to find out about the chemical process that takes place when pipes rust. Make links between the examples you find and the law of conservation of mass. Share your findings with a classmate.

Success criteria

- I can distinguish between an open and a closed system, with reference to conservation of mass.
- I can explain the law of conservation of mass and how it applies to chemical reactions.

6·2 ▸ Naming chemical compounds

Learning intention

At the end of this lesson, I will be able to construct scientific names and formulas for chemical compounds using scientific conventions.

Key terms

chemical formula: chemical symbols showing the ratio of elements to one another in a compound

polyatomic ion: two or more ions bonded together and acting as a single charged unit

prefix: letters or numbers placed before the stem of a word

Content group: Chemical reactions

Table 6.2: Numbers of atoms and their corresponding prefix

Number of atoms	Prefix
1	mono-
2	di-
3	tri-
4	tetra-
5	penta-
6	hexa-
7	hepta-
8	octa-

▲ **Figure 6.6:** Iron can have different ionic forms: iron(II) and iron(III). Both are soluble in water, but they form different-coloured solutions.

Identifying and naming chemical compounds is essential to understanding chemical reactions. In Focus Area 3, we learnt about identifying and naming organic compounds, and about the structure and formulas for some inorganic molecules and compounds. In this section, you will expand upon your knowledge of naming chemical substances.

Rules for naming inorganic compounds

Rules for naming non-organic covalent molecular compounds

Many compounds have common names (e.g. water, bleach) as well as their scientific names, which are names for discrete molecules based on their **chemical formula**. Elemental symbols and numerical subscripts represent the type and ratio of atoms in a substance.

Scientists follow certain rules when naming covalent molecular compounds:

1 Name the first element in the formula.

2 Name the second element, giving it the ending of 'ide'; for example, carbon fluor*ide* (CF), hydrogen chlor*ide* (HCl).

3 If there is more than one of a particular atom in the formula, use a **prefix** to indicate the number of that type of atom (Table 6.2); for example, *di*phosphorus *pent*oxide (P_2O_5), carbon *di*oxide (CO_2), *di*hydrogen *mono*oxide (i.e. H_2O – or water).

Prefix to indicate the number of that type of atom (Table 6.2)

di hydrogen mon oxide

First element in the formula (H)

Second element in the formula, ending with '–ide'

Rules for naming ionic compounds

The name of an ionic compound is the name of the cation followed by the name of the anion. Metallic cations are named after their element name, whereas simple anions have the suffix '-ide' in place of the last letters

◀ **Figure 6.7:** Sodium metal + chlorine gas forms sodium chloride.

of the element name. For example, chlorine becomes the anion chlor*ide*, which indicates it has gained an electron. When a sodium atom and a chlorine atom form ions and an ionic bond, the resulting compound is named sodium chloride. (See Section 3.7 in Focus Area 3 for examples of cations and anions.)

Sometimes, roman numerals are included in the name to differentiate between metals with more than one possible valency or ionic form. For example, iron can exist as Fe^{2+} and Fe^{3+}, which form different compounds: iron(II) chloride and iron(III) chloride.

Naming becomes more complicated for complex cations and anions. **Polyatomic ions** are made up of more than one type of atom bonded together. For example, carbonate is made up of one carbon atom and three oxygen atoms and has an overall negative charge of 2– (CO_3^{2-}). Any ionic compound it forms can be named by using the same systematic approach as stated above:

sodium carbonate

(cation name) (anion name)

Table 6.3 shows some common polyatomic ions and their ion symbols.

Table 6.3: Some common polyatomic ions

Name	Formula
Ammonium	NH_4^+
Carbonate	CO_3^{2-}
Hydroxide	OH^-
Nitrate	NO_3^-
Phosphate	PO_4^{3-}
Sulfate	SO_4^{2-}
Hydrogen carbonate	HCO_3^-
Dichromate	$Cr_2O_7^{2-}$

Note the following when writing ionic chemical formulas that include polyatomic ions:

- If there is more than one polyatomic ion, write the ion in brackets and the quantity as a subscript after the brackets; for example, $(CO_3)_2$ shows there are two carbonate ions.
- Do not change subscript values within polyatomic ion symbols; for example, the '3' in a carbonate ion (CO_3) must *always* be a '3'.

Learning Ladder

Reactions

1. Classify the following compounds as ionic or covalent.
   - **a** FeS
   - **b** CO
   - **c** $PbSO_4$
   - **d** H_2O_2
   - **e** $Ca(OH)_2$
2. **a** For the ionic substances in Question 1, identify (by name) the cation and anion.
   b Name the compounds in Question 1.
3. Write the name for each of the following nitrogen oxides: NO, NO_2, N_2O, N_2O_5, N_2O_4
4. For the compounds listed in Question 3, investigate the similarities and differences in their properties and uses. Construct a table to organise your findings.

Questioning and predicting

see page 401

1. Identify which of the following questions would be most appropriate to investigate how chemical substances are named.
   - **a** How does the name of a covalent molecule relate to its chemical make-up?
   - **b** Does the name of an ionic compound have anything to do with its structure?
2. Rewrite the less appropriate question from Question 1 so it can be used to investigate a scientific concept.
3. Propose a hypothesis to predict the outcome of an investigation that asks the scientific question from either Question 1 or Question 2.
4. Suggest how you could ensure that your question and hypothesis could account for the controlled variables required in an investigation.

In context

'Baking soda' is the common name for an inorganic substance. Conduct an online search to determine the scientific name for baking soda. Think of more common names for substances that might have a scientific name, and conduct a search to identify the names. Share your findings with a classmate.

Success criteria

- I can use rules to scientifically name inorganic covalent and ionic compounds.
- I can interpret names of chemical substances in order to write simple chemical formulas.

6.3 ▸ Constructing chemical equations

Learning intention

At the end of this lesson, I will be able to represent chemical reactions using word equations by constructing balanced chemical equations.

Key terms

aqueous: dissolved in water, or in an aqueous solution

chemical equation: a chemical reaction represented using chemical formulas of reactants and products

coefficient: a number placed before the chemical in a formula or chemical equation

skeleton equation: a chemical equation that has not been completed and/or balanced

species: a specific form of chemical substance involved in a reaction

sublime: to change state from solid to gas without passing through a liquid phase

word equation: a representation of a chemical reaction using the names of the reactants and products

Investigation 6.3

Simulating chemical reactions, page 539

Content group: Chemical reactions

Chemical reactions can be represented in several ways. Word equations give the names of the substances involved in a reaction, while chemical equations use chemical formulas to show the arrangement of atoms before and after a reaction. The molecules before and after a reaction may be different, but the total mass never changes. Therefore, chemical equations also demonstrate how chemical reactions obey the law of conservation of mass.

Start by listing the reactants and the products

The first step in writing a **chemical equation** is to list all the substances, or **species**, involved. The reactants are the substances that you start with before the reaction takes place. The products are the substances that you have after the reaction has taken place.

Write the reactants on the left side of an arrow, and the products on the right side, using plus signs if there are two or more species:

Reactants → products

Although we use chemical formulas in chemical equations, it is often easiest to start by writing the names of the species. This is known as a **word equation**. You can then write the formulas underneath the words.

Figure 6.8: Producing ammonia fertiliser from nitrogen in the air allows farmers to grow more crops.

An example of a simple chemical reaction is where nitrogen gas (N_2) and hydrogen gas (H_2) combine to form ammonia gas (NH_3), which is an important component of fertilisers. This takes place at high temperatures. To write a chemical equation for this reaction, write the word equation and then state the chemical formulas underneath for the **skeleton equation**:

Word equation: Nitrogen + hydrogen → ammonia

Skeleton equation: $N_2 + H_2 \rightarrow NH_3$

In a skeleton equation, the words have been replaced with chemical formulas, but it may not be the balanced or complete equation. How to balance and complete a chemical equation is explained below.

Balance the number of atoms on each side

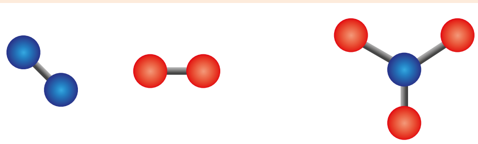
The law of conservation of mass says that matter cannot be created or destroyed. Whenever it looks as though matter has been destroyed, it has usually been lost as a gas.

In a chemical reaction, the atoms of the reactants rearrange to form the molecules of the products. Because no new atoms can be created or destroyed, this means that the number of atoms of each type of element must be the same on both sides of the equation. If the numbers do not match, you need to balance the equation by adding more molecules to one or both sides. Do this by adding **coefficients** (numbers) in front of the reactants or products to show that there are more molecules of that substance.

Consider the ammonia formation equation.

Step 1 Write out the chemical equation for the reaction.

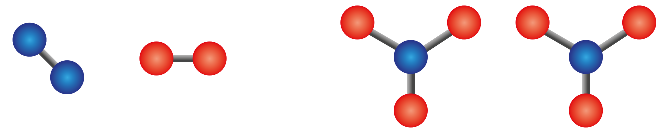
$$N_2 + H_2 \rightarrow NH_3$$



This equation is unbalanced because there is not the same number of nitrogen atoms and hydrogen atoms on each side.

Step 2 Balance the number of nitrogen atoms by adding a 2 in front of the NH_3 on the right-hand side:

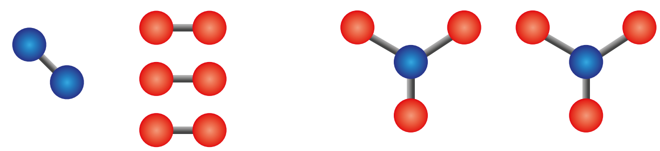
$$N_2 + H_2 \rightarrow 2NH_3$$



There are now two nitrogen atoms on each side of the equation. However, the hydrogen atoms are still unbalanced – there are two hydrogen atoms on the left-hand side, but $2 \times 3 = 6$ on the right-hand side. To balance it, more hydrogens are needed on the reactant side.

Step 3 Put a 3 in front of the H_2 on the left-hand side so there are 6 in total:

$$N_2 + 3H_2 \rightarrow 2NH_3$$



The equation is now balanced, with the same number of atoms on each side. The equation also shows us that one nitrogen molecule and three hydrogen molecules react to form two ammonia molecules.

Figure 6.9: Ammonia molecules are made up of nitrogen and hydrogen atoms in a one-to-three ratio (N:H = 1:3). This is achieved by reacting specific amounts of nitrogen gas and hydrogen gas to allow a balanced chemical reaction.

Indicate the state for each species using symbols

To complete a chemical equation, we use state symbols after the chemical formula to show the physical state of each species:

- (s) – solid
- (l) – liquid
- (g) – gas
- (aq) – **aqueous** (the substance is dissolved in water or is an 'aqueous' solution).

For example, when solid sodium chloride is dissolved in water, it can be represented by the following equation:

$$NaCl(s) \xrightarrow{H_2O} NaCl(aq)$$

Including state symbols in a chemical equation provides essential information about the physical state of each substance involved, which helps us to better understand the reaction's context and conditions. State symbols – (s) for solids, (l) for liquids, (g) for gases, and (aq) for aqueous solutions – reveal how substances can interact chemically. For instance, knowing whether a substance is dissolved in water (aq) or exists as a gas (g) can influence reaction rates, predict solubility, and clarify safety or environmental considerations.

The state of each reacting species determines what type of reaction will occur, if at all. For example, when ionic salts are mixed with one another, they will only react if they are first dissolved in water, which frees the ions from their solid lattice. If solid salts are combined, a mixture is formed rather than a new chemical substance, which does not result in a chemical reaction.

(a) Solid

Solid carbon dioxide is very cold and will **sublime** into gas very quickly at room temperature.

(b) Liquid

Liquid carbon dioxide is a colourless substance that only exists at high pressures. This cartridge contains liquid carbon dioxide; however, as soon as it escapes, it becomes a gas.

(c) Gas

Solid carbon dioxide sublimes directly into carbon dioxide gas, which has a smoky appearance.

(d) Aqueous

Carbon dioxide can be dissolved in water under pressure. You cannot see the carbon dioxide until you open the bottle and it bubbles out in gas form.

Figure 6.10: The same compound can look and behave very differently depending on the state it is in. Here is carbon dioxide in all its state forms: (a) solid, (b) liquid, (c) gas, and (d) aqueous.

Figure 6.11: When solid salts are combined, a chemical reaction will not occur. The salts must be aqueous (dissolved in water) to allow their ions to interact if a chemical reaction is to take place.

Understanding state symbols helps us better visualise and describe what happens during a chemical reaction. There are usually enough describing words given to determine the state symbols of the species involved in a chemical reaction. For instance, the description of the formation of ammonia on the previous page indicated that all the species involved are gaseous; therefore, the balanced and complete chemical equation for the reaction is:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Equally, when given a complete and balanced chemical equation, you should be able to describe the chemical reaction based on the information provided in the equation. Consider the following balanced chemical equation, which represents one method of iron corrosion:

$$4Fe(s) + 3O_2(aq) + 6H_2O(l) \rightarrow 4Fe(OH)_3(s)$$

A description can be written to describe the chemical reaction, even if the details of how it happens are not fully understood:

> *When solid iron metal is exposed to oxygen gas dissolved in liquid water, the three species react to form solid iron hydroxide.*

Overall, state symbols enhance the accuracy and clarity of chemical equations, making them a valuable tool for studying and communicating chemical processes.

Learning Ladder

Reactions

1. Propose the state symbol for each of the following chemical species.
   - **a** Methane vapour
   - **b** Ionic salt dissolved in solution
   - **c** Copper metal
   - **d** Liquid octane
2. **a** Describe what the reactants and products are in a chemical reaction.
   - **b** Consider the chemical reaction:
     $2Na + 2H_2O \rightarrow 2NaOH + H_2$.
     Identify the:
     - **i** reactants.
     - **ii** products.
     - **iii** number of hydrogen atoms in each of the reactants and products.
3. Explain how chemical equations demonstrate the law of conservations of mass. Use examples to support your response.
4. Balance the following chemical equations.
   - **a** $Zn + HCl \rightarrow ZnCl_2 + H_2$
   - **b** $P_4 + O_2 \rightarrow P_2O_5$
   - **c** $NaBr + Cl_2 \rightarrow NaCl + Br_2$
5. Iron(III) oxide (Fe_2O_3) reacts with solid carbon to form carbon dioxide gas and iron metal.
   - **a** Write a word equation to represent this reaction.
   - **b** Write a complete and balanced chemical equation to represent this reaction.
   - **c** Conduct an online search to determine where and when this reaction is likely to occur, and for what purpose.

Observing

see page 398

1. Identify the models in this section that allowed you to view the number of each molecule, so that a chemical equation could be correctly balanced.
2. Use step 3 for balancing the equation for the formation of ammonia to observe and record the number of each type of atom – nitrogen (N) and hydrogen (H) – involved in the chemical reaction.
3. Consider the chemical equation for the formation of ammonia.
   - **a** Which reactant do you need more of to form ammonia?
   - **b** Which reactant would run out first if you have 6 molecules of nitrogen and 15 molecules of hydrogen? How much of the excess reactant would you have left over?
4. For the equation $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$, if there are three molecules of N_2, how many molecules of H_2 are required, and how many molecules of NH_3 are produced? Explain your answer.

In context

Choose a chemical reaction commonly used in industry, such as the Haber process for making ammonia or the combustion of fossil fuels for energy. Conduct an online search to explain how your chosen reaction benefits society. Discuss its potential environmental impacts, and describe how the industry manages these impacts while still meeting global demands.

Success criteria

- I can construct word equations from observations and written descriptions of a range of chemical reactions.
- I can balance and complete chemical equations by making sure that the number and types of atoms are the same on both sides of the arrow, and by including state symbols.

6·4 ▸ Synthesis and decomposition reactions

Learning intention

At the end of this lesson, I will be able to describe the features of synthesis and decomposition reactions.

Key terms

corrosion: the degradation of a metal due to reacting with its environment

decomposition reaction: a reaction in which one reactant breaks down to form multiple products

degradation: deterioration of physical properties of a material

rusting: the corrosion of iron to form iron oxides

synthesis reaction: a reaction in which two or more reactants combine to form a more complex product

Investigation 6.4A

Synthesis of iron oxide, page 541

Investigation 6.4B

Decomposition of copper(II) carbonate, page 543

Content group: Chemical reactions

In some chemical reactions, reactants combine to form a single product; in others, a complex reactant might break down into simple parts.

Synthesis reactions combine substances

A chemical reaction that involves two or more reactants combining to form a single, more complex product is called a **synthesis reaction**. In general, a chemical equation for a synthesis reaction looks like this:

Reactant A + reactant B → product AB

$$A + B \rightarrow AB$$

An example is the formation of water from the gases of hydrogen and oxygen.

Hydrogen gas + oxygen gas → water

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$$

Corrosion is a synthesis reaction

Corrosion is a natural process that involves the gradual **degradation** of metals by chemical reactions with substances in their environment. When metals react with oxygen, compounds form on the surface of the metals. The oxygen can be in the air, water or salt water. Corrosion affects the properties of a metal structure, such as its strength and appearance.

Iron corrodes to create rust

Rusting is the corrosion of iron. The scientific name for rust is iron(II) oxide (Fe_2O_3), and it forms so easily that pure iron is rarely found in nature. Rust forms as a flaky red–brown solid on iron structures. For rusting of iron to occur, oxygen is required:

Iron + oxygen → iron(II) oxide

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

Rust causes a lot of damage to buildings, cars and ships because it does not form a protective layer on the metal's surface. Water can get through to the metal underneath, leading to further corrosion. Little bits of rust flake off, leaving the rest of the metal exposed to oxygen. Eventually, all the metal corrodes.

Figure 6.12: The iron in this old car has corroded to produce orange–brown rust.

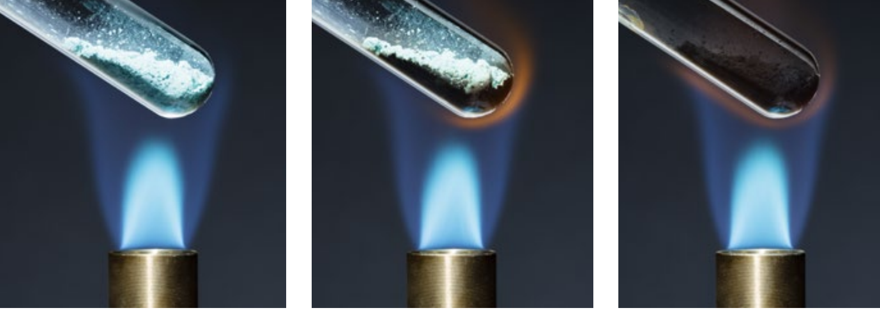


Figure 6.13: Heating a metal carbonate causes it to decompose and produce the metal oxide and carbon dioxide gas.

Decomposition reactions break down substances

In **decomposition reactions**, one substance breaks down into two or more simpler substances. Opposite to a synthesis reaction, a chemical equation for a decomposition reaction looks like this:

$$\text{Reactant AB} \rightarrow \text{product A} + \text{product B}$$
$$AB \rightarrow A + B$$

Most decomposition reactions require energy to get them started. Thermal decomposition is started by heat energy. This is an easy reaction to see in the laboratory, if you heat a reactive substance over a Bunsen burner. For example, if you heat copper(II) carbonate, it decomposes into copper oxide and carbon dioxide gas:

$$\text{Copper(II) carbonate} \xrightarrow{\text{heat}} \text{copper oxide} + \text{carbon dioxide}$$
$$CuCO_3(s) \xrightarrow{\text{heat}} CuO(s) + CO_2(g)$$

Electrical decomposition – electrolysis – is usually performed by passing an electrical current through a liquid reactant. For example, if you apply electricity to water, it decomposes into hydrogen and oxygen:

$$\text{Water} \xrightarrow{\text{electricity}} \text{hydrogen} + \text{oxygen}$$
$$2H_2O(l) \xrightarrow{\text{electricity}} 2H_2(g) + O_2(g)$$

Photochemical decomposition is a very slow reaction triggered by light energy. For example, when silver chloride is exposed to light, it slowly decomposes into silver and chlorine ions:

$$\text{Silver chloride} \xrightarrow{\text{light}} \text{silver ions} + \text{chlorine ions}$$
$$AgCl(aq) \xrightarrow{\text{light}} Ag^+(aq) + Cl^-(aq)$$

Learning Ladder

Reactions

1. Identify the following reactions as synthesis or decomposition:
   - **a** $2H_2O_2\,(l) \rightarrow O(l) + O_2(g)$
   - **b** $CaCO_3\,(s) \rightarrow CaO(s) + CO_2(g)$
   - **c** $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$
   - **d** $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$
2. **a** Describe corrosion as a synthesis reaction, with reference to examples.
   b Write word equations for each of the reactions in Question 1. (Revisit Section 6.3 to remind yourself how to write a word equation.)
3. Corrosion, thermal decomposition, electrolysis and photochemical reactions require more than just the reactants to start a reaction.
   a Identify the factors required for each reaction.
   b Propose why these factors are needed for the reaction to occur.
4. Explain how you can use word equations and chemical equations to determine if a reaction is a synthesis or decomposition reaction.

Planning investigations

see page 405

Imagine you wanted to compare how long it takes for different metal carbonates to decompose on heating.

1. Identify the risks involved in decomposing metal carbonates over heat, and describe how to minimise these risks. (Hint: See Figure 6.13.)
2. Identify the independent, dependent and controlled variables for this investigation.
3. Propose an aim for the investigation.
4. **a** Write a method that addresses the aim of the investigation.
   b Identify the features of the method that make it ethical, reliable and valid.
   c If the features you identified in part b are not sufficient, modify the method to ensure an ethical, reliable and valid investigation.

In context

You are given a gold coin, an iron nail, a piece of copper plate and some aluminium foil. Which do you think will corrode the fastest, and why? Write a method to test your hypothesis.

Success criteria

- I can distinguish between synthesis and decomposition reactions.
- I can describe some examples of synthesis and decomposition reactions.

6.5 ▸ Displacement reactions

Learning intention

At the end of this lesson, I will be able to describe the features of displacement reactions.

Key terms

displacement reaction: a reaction in which an element replaces (displaces) another element from a compound

dissociate: to split apart into ions in water; to dissolve ionic compounds

double-displacement reaction: a reaction in which parts of two compounds replace each other to form two new compounds

net ionic equation: a chemical equation that only includes the ions and precipitate involved in the reaction; not spectator ions

precipitate: an insoluble product that forms a solid in solution

precipitation reaction: a type of double displacement reaction that forms a precipitate when two solutions are combined

single-displacement reaction: a reaction in which a more reactive element replaces a less reactive element from a compound

spectator ion: an ion that does not take part in the reaction

Investigation 6.5A

Growing metallic crystals: metal displacement reactions, page 545

Investigation 6.5B

Precipitation reactions, page 547

Content group: Chemical reactions

In some reactions, an element displaces another element in a compound. A single element might replace another element, or two elements of two different compounds may replace each other.

In single-displacement reactions, one element replaces another element

Displacement reactions occur when an element replaces another element in a compound. When one element displaces another element in a compound, it is called a **single-displacement reaction**. This typically happens when a more reactive element replaces a less reactive one in a compound. In the general equation in Figure 6.14, element A is more reactive than element B, so A forms a chemical bond with C, causing B to be displaced from the compound.

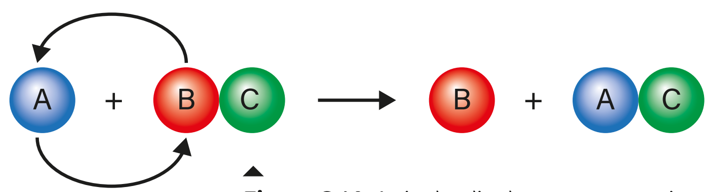


Figure 6.14: A single-displacement reaction

Single-displacement reactions often occur between metals and ionic salts. For example, when a piece of zinc metal is placed in copper sulfate solution, zinc displaces copper to form zinc sulfate and solid copper:

$$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$$

In this case, zinc is more reactive than copper and, therefore, displaces it from the ionic solution.

Figure 6.15: Zinc is more reactive than copper, so when zinc metal is placed in a solution of copper(II) sulfate, the zinc replaces the copper in solution and solid copper forms.

The activity series is used to predict displacement reactions

To determine whether a displacement reaction will occur, we can use the activity series of metals, as shown in Figure 6.16. If pure, solid metal is more reactive than the metal cation in solution, then a reaction will occur. For example, zinc is above copper on the activity series, indicating that it will displace copper from its compound, forming solid copper.

Lithium (Li)
Potassium (K)
Barium (Ba)
Calcium (Ca)
Sodium (Na)
Magnesium (Mg)
Aluminium (Al)
Zinc (Zn)
Chromium (Cr)
Iron (Fe)
Tin (Sn)
Lead (Pb)
Copper (Su)
Silver (Ag)
Plutonium (Pt)
Gold (Au)

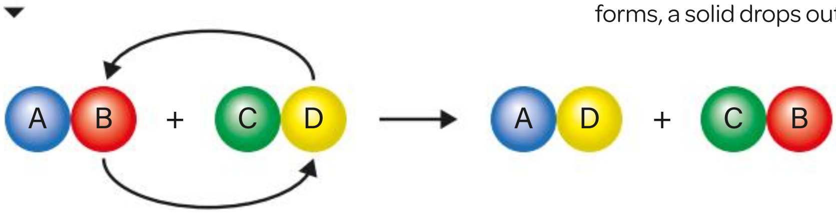
Increasing activity

Figure 6.16: This simplified activity series of metals can be used to determine if a displacement reaction will occur when a metal is combined with an ionic compound in solution.

Double-displacement reactions involve two elements of two different compounds swapping

When parts of two compounds replace each other to form two new compounds, this is called a **double-displacement reaction**. In general, a double-displacement reaction looks like Figure 6.17.

Figure 6.17: A double-displacement reaction



These reactions typically occur in aqueous solutions and ions are exchanged between the reacting compounds. For example, when sodium chloride and silver nitrate solutions are mixed, a double-displacement reaction occurs, forming sodium nitrate and silver chloride:

$$NaCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$

Precipitates can form in double-displacement reactions

A **precipitation reaction** occurs when two salt solutions are mixed, and two new products are formed: an insoluble solid and a soluble salt. The insoluble solid, called a **precipitate**, may be suspended for a while but eventually settles to the bottom of the container. Precipitation reactions can be used to identify the presence of certain compounds or ions.

Figure 6.18: Solutions are clear liquids. When a precipitate forms, a solid drops out of the solution.

Ionic compounds can form precipitates

Most ionic compounds are soluble in water, so when they are mixed with water, the water molecules pull them apart and they **dissociate** into freely moving ions. The ions are then available to form new compounds with other ions. If the new compound is insoluble, a solid precipitate will form.

Consider what happens when solutions of potassium iodide and lead nitrate are mixed together. The potassium iodide solution is made up of positive potassium ions (K^+) and negative iodide ions (I^-). The lead nitrate solution is made up of positive lead ions (Pb^{2+}) and negative nitrate ions (NO_3^-). Once these ions are mixed, a precipitation reaction occurs, and the insoluble lead and iodide ions combine to form a solid. This produces a solution of potassium nitrate, with a precipitate of insoluble yellow lead iodide forming within it (Figure 6.19).

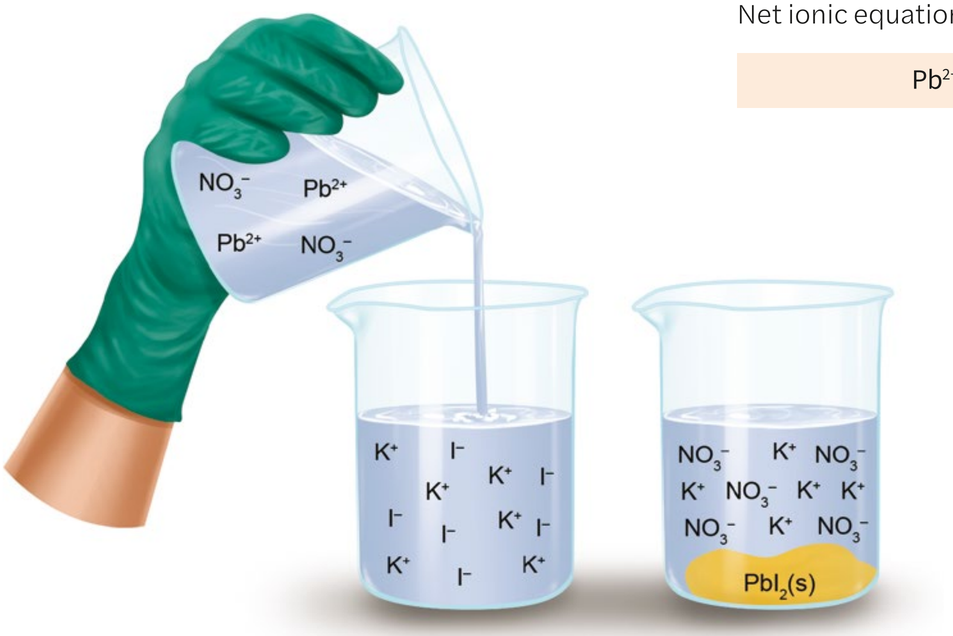


Figure 6.19: The precipitation reaction of potassium iodide with lead nitrate

The potassium cation and the polyatomic nitrate anion do not take part in the reaction. They are called **spectator ions** because they are not involved in the reaction. They are shown in the complete ionic equation for the reaction but not in the **net ionic equation**:

Potassium iodide	+	lead nitrate	→	lead iodide	+	potassium nitrate
$2KI(aq)$	+	$Pb(NO_3)_2(aq)$	→	$PbI_2(s)$	+	$2KNO_3(aq)$

Complete ionic equation:

$$2K^+ + 2I^- + Pb^{2+} + 2NO_3^- \rightarrow PbI_2 + 2K^+ + 2NO_3^-$$

Cancel out the spectator ions:

$$\cancel{2K^+} + 2I^- + Pb^{2+} + \cancel{2NO_3^-} \rightarrow PbI_2 + \cancel{2K^+} + \cancel{2NO_3^-}$$

Net ionic equation:

$$Pb^{2+}(aq) + 2I^-(aq) \rightarrow PbI_2(s)$$

Figure 6.20: When a solution of potassium iodide is added to a solution of lead nitrate, a yellow precipitate of lead iodide is formed.

Solubility rules help to identify precipitates

If a reaction produces a precipitate, you may want to identify it. The solubility rules (see Table 6.4) are rules for ionic compounds that tell you whether certain ions will form precipitates with other ions or stay dissolved in solution.

For example, the rules tell you that in the previous reaction of potassium iodide with lead nitrate, all nitrates are soluble but lead iodide is insoluble. This helps to identify the yellow precipitate as lead iodide. Similarly, you can see that sodium chloride (table salt) is soluble but silver chloride is not soluble.

Table 6.4: The solubility rules

Ions	Solubility
Group 1 salts (Na^+, K^+)	All soluble
Ammonium salts (NH_4^+)	All soluble
Nitrates (NO_3^-)	All soluble
Chlorides (Cl^-)	All soluble except for AgCl, $PbCl_2$ and $Hg_{C}l2$
Iodides (I^-)	All soluble except for AgI, PbI_2 and HgI_2
Sulfates (SO_4^{2-})	All soluble except for $PbSO_4$, $CaSO_4$ and $BaSO_4$
Carbonates (CO_3^{2-})	All insoluble except for group 1 carbonates (e.g. Na_2CO_3, K_2CO_3) and $(NH_4)_2CO_3$
Hydroxides (OH^-)	All insoluble except for group 1 hydroxides (e.g. NaOH, KOH), $Ca(OH)_2$, $Ba(OH)_2$ and NH_4OH

Learning Ladder

Reactions

1. Classify the following reactions as single or double displacement.
   - **a** Copper metal + silver nitrate → silver metal + copper(II) nitrate
   - **b** Sodium chloride + copper(II) nitrate → sodium nitrate + copper(II) chloride
   - **c** Magnesium chloride + potassium fluoride → potassium chloride + magnesium fluoride
   - **d** Zinc metal + iron(II) sulfate → iron metal + zinc sulfate
2. Describe general observations that indicate a displacement reaction has occurred.
3. Explain how the observations of a reaction would help you to distinguish between single- and double-displacement reactions. Provide examples.
4. Write the net ionic equations, including state symbols, for the following reactions. You may use the solubility rules to help you.
   - **a** $NaCl + AgNO_3 \rightarrow NaNO_3 + AgCl$
   - **b** $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$
   - **c** $2NaOH + CuSO_4 \rightarrow Na_2SO_4 + Cu(OH)_2$
   - **d** $BaCl_2 + K_2SO_4 \rightarrow BaSO_4 + 2KCl$
   - **e** $FeI_2 + 2KOH \rightarrow 2KI + Fe(OH)$
5. Propose how displacement reactions could be used to remove the following contaminants from waterways (include reference to the type of displacement reaction, activity series, solubility rules):
   - **a** lead.
   - **b** sulfate.
   - **c** chromium.
   - **d** phosphate.

Questioning and predicting

see page 401

1. Identify the question that would be most suitable to investigate scientifically.
   - **A** How can I tell if copper is more reactive than zinc?
   - **B** Does temperature affect the rate of the formation of ionic precipitates?
   - **C** How does the concentration of ionic solutions affect the rate of metal displacement?
2. Construct a scientific question that could be used to investigate the relative reactivities of copper, zinc, silver and iron.
3. Several different metals were mixed with several different ionic compounds dissolved in solution. Write a hypothesis to predict whether a reaction will take place, based on the activity series.

In context

Conduct a search to learn about how a metal is mined and refined. Summarise the process, including details of any displacement reactions used. Also make reference to the reactivity series and/or solubility.

Success criteria

- I can use the activity series to predict if a displacement reaction will occur.
- I can use solubility rules to predict the formation of a precipitate, based on the combined solutions.

6·6 ▸ Acids, bases and pH

Learning intention

At the end of this lesson, I will be able to identify whether a substance is acidic or basic, based on its pH.

Key terms

acid: a substance with a pH of less than 7

alkali: a base that is dissolved in water

base: a substance with a pH of more than 7

caustic: able to burn or corrode organic tissue through chemical action

concentration: the amount of a substance in a volume of solution

corrosive: highly reactive and damaging or destructive to another substance

ionic salt: a compound made up of a cation and an anion

neutralise: to make something chemically neutral; neither acidic nor basic

pH: a figure expressing the acidity or alkalinity of a solution

Investigation 6.6A

Cleaning coins, page 549

Investigation 6.6B

Acid or base? The pH of common household substances, page 550

Content group: Chemical reactions

Two of the most commonly occurring groups of compounds are acids and bases. They are commonly used in cleaning products, swimming pools and kitchens. Many of the foods we eat are either acidic or basic. The acids and bases in foods help us to digest them.

Acids produce hydrogen ions

An **acid** is a **corrosive** chemical substance that produces hydrogen ions, or protons (H^+), when mixed with water. The hydrogen ions can react with the other substances to produce water and hydrogen gas, as well as **ionic salts**, which are made up of cations and anions.

The higher the **concentration** of hydrogen ions produced by an acid, the higher its acidity. Strong acids are very dangerous, especially when they contact skin and eyes. That is why you must always wear protective clothing and eyewear when working with acids in the laboratory.

Weak acids are important in our diet. Citrus fruits contain a weak acid, called citric acid, which contributes to their sour flavour. Soft drinks, coffee and vinegar also contain weak acids.

Bases produce hydroxide ions

A **base** is a substance that reacts with an acid to **neutralise** it. Bases that dissolve in water are called **alkalis**. When mixed with water, bases produce hydroxide ions (OH^-) – an atom of oxygen bonded to an atom of hydrogen, with an overall negative charge.

Strong bases are described as **caustic**, meaning they cause burns by chemical action; therefore, they can be just as dangerous as acids. Household cleaning products are strong bases. Bases such as sodium hydroxide and ammonia react with oils and fats, which is why they are used in many household cleaners. Weak bases are found in toothpaste, conditioners, antacid tablets and baking powder.

There are three types of bases.

- Metal hydroxides (e.g. potassium hydroxide) contain metals bonded with hydroxide (OH^-).
- Metal oxides (e.g. zinc oxide) contain metals bonded with oxide ions (O^{2-}).
- Metal carbonates (e.g. copper carbonate) contain metals bonded with carbonate ions (CO_3^{2-}).

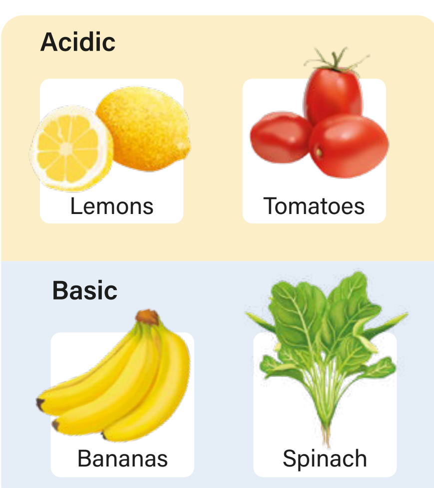


Figure 6.21: Weak acids and bases occur naturally in some foods.

The pH scale measures acidity

The acidity of a solution is measured on a scale called the **pH** scale. The higher the proportion of H^+ ions, the lower the pH. Therefore, the lower the proportion of H^+ ions in a solution compared to hydroxide ions (OH^-), the higher the pH. Acids have a low pH, while bases have a high pH. A solution with a pH of 7 is neutral, a solution with a pH of less than 7 is acidic, and a solution with a pH greater than 7 is basic. Pure water is neutral because it has a pH of 7 at 25 °C.

You can measure pH by using a digital pH meter, or by adding an indicator to a solution and matching its colour to a chart. Indicators change colour depending on whether they are mixed with an acid or a base. A common indicator is litmus, which turns red when mixed with acids and blue when mixed with bases.

Figure 6.22: This symbol is used on containers to warn that the chemical inside is corrosive and should be handled with care.

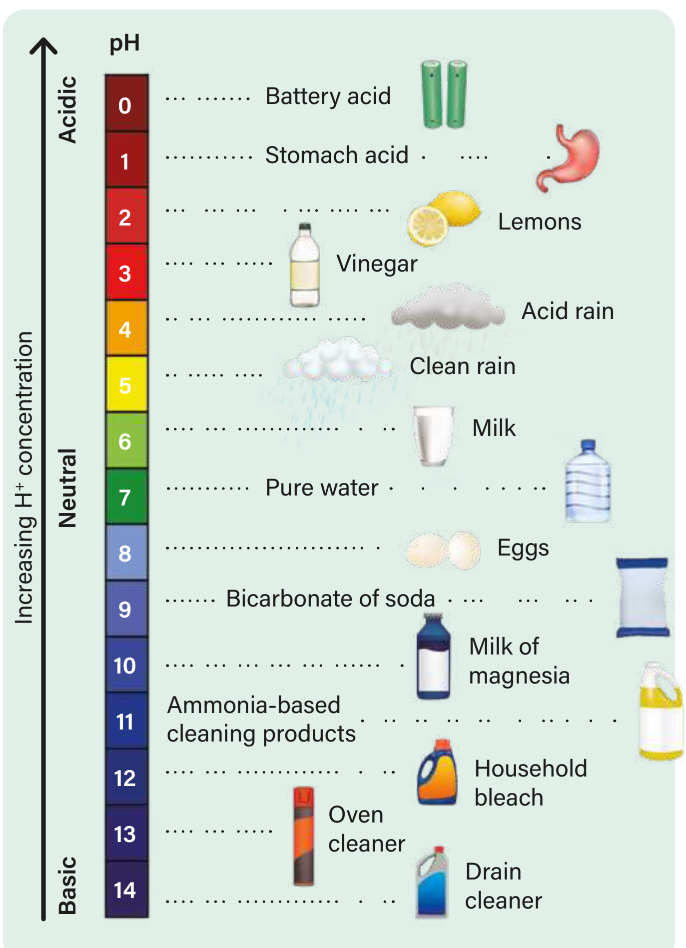


Figure 6.23: The pH scale

Learning Ladder

Reactions

1. Copy and complete these sentences.
   Acids have a pH range of ____________. *Bases have a pH range of* ____________.
2. Describe two observations that could be used to identify:
   a an acid.
   b a base.
3. Explain why strong acids and bases can be dangerous.
4. Propose what you might do to increase the pH of an acidic solution.

Conducting investigations

see page 408

1. Describe two pieces of equipment that increase safety when handling strong acids and bases.
2. Propose two types of equipment or materials that could be used to measure the acidity of a solution.
3. Read the aim and method for Investigation 6.6A on page 549. Based on the type of data being collected and the results table, propose two errors in the method.
4. Propose modifications to the method that could improve the precision of the results.

In context

Conduct a search to identify common substances for each value of the pH scale not already included in this section. Construct a poster similar to Figure 6.23 to include the substances you identified in your search, as well as their role in society and any safety considerations. Present your poster to the class.

Success criteria

- I can explain what acids and bases are and give examples of each.
- I can describe the pH scale, including the ranges for acids and bases.

6·7 ▸ Neutralisation and other reactions of acids

Learning intention

At the end of this lesson, I will be able to describe the features of neutralisation reactions and other reactions of acids.

Key terms

carbonate: a substance containing the elements carbon and oxygen

indicator: a substance used to determine the acidity of a solution

neutralisation reaction: a reaction involving an acid and a base to produce water and a salt

strong acid: an acid that ionises completely in water

weak acid: an acid that partially ionises (loses or gains electrons) in water

Investigation 6.7A

Neutralising hydrochloric acid, page 552

Investigation 6.7B

The effects of indicators on acids and bases, page 554

Investigation 6.7C

Reactions of acids with metals, page 556

Investigation 6.7D

Reactions of acids with carbonates, page 558

Content group: Chemical reactions

Acids can be dangerous because they are corrosive. Some metals are very reactive when exposed to acids, producing hydrogen gas and metallic salts. But when an acid and a base react, they neutralise each other, making the products safer.

Acids and bases neutralise each other

In a **neutralisation reaction**, an acid and a base react to form a salt and water. This happens because acids are a source of hydrogen ions (H^+), while bases are a source of hydroxide ions (OH^-). In an acid–base neutralisation reaction, the H^+ from the acid and the OH^- from the base combine to form water, which is neutral, having a pH of 7 at 25 °C.

$$\text{Hydrogen ion} + \text{hydroxide} \rightarrow \text{water}$$
$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

The other parts of the acid and base combine to produce a salt. The reaction of a **strong acid** with a strong base results in a neutral solution with a pH of 7 and a neutral ionic salt. For example, nitric acid reacts with sodium hydroxide to form the salt lithium nitrate ($LiNO_3$) and water.

$$\text{Nitric acid} + \text{lithium hydroxide} \rightarrow \text{salt} + \text{water}$$
$$HNO_3(aq) + LiOH(aq) \rightarrow LiNO_3(aq) + H_2O(l)$$

The reaction of a strong acid with a weak base produces a solution with pH <7, containing water and an acidic salt. The reaction of a strong base with a **weak acid** produces a solution with pH >7, containing salt and water.

Figure 6.24: Universal indicator turns different colours depending on the pH.

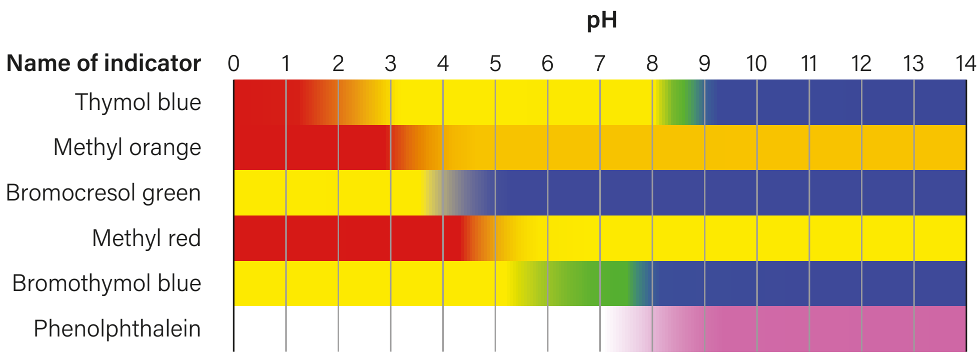


Figure 6.25: Common pH indicators showing the colour changes that occur at specific pH values.

Indicators can be used to measure pH

Different **indicators** show a wide range of colour changes depending on the pH of a solution. For example, a universal indicator can show multiple colours to indicate the exact pH level from 1 to 14, from red in strong acids to violet in strong bases (Figure 6.24).

Some indicators only display two or three colours throughout the pH range. This can be useful when we are only concerned about whether a substance is above or below a certain pH. Figure 6.25 shows a variety of different indicators and their colour changes at specific pH values. For example, bromocresol green changes from yellow to blue at pH 4–5, so it would not be able to identify with certainty if a solution is basic (alkaline), though it could identify if its pH is above or below 4–5.

Acids react with metals to produce salts and hydrogen gas

Acids react with metals. Some metals are more reactive than others. You can see this in the activity series of metals in Table 6.5. The metals at the top of the reactivity series, such as potassium and sodium, react violently, while those at the bottom react very little. This is one reason that gold and silver are used to make jewellery, rather than iron and zinc. Gold and silver are chemically very unreactive, and they keep their shiny surface even when exposed to acids and oils in the air or on your skin.

Acids react with metals to form salts and hydrogen gas. More reactive metals react faster, which you can see by how fast the hydrogen gas bubbles are released.

Acid + metal → salt + hydrogen

The salt formed depends on the acid the metal reacts with. For example, magnesium reacts with hydrochloric acid to produce magnesium chloride and hydrogen gas.

Hydrochloric acid + magnesium → magnesium chloride + hydrogen

$$2HCl(aq) + Mg(s) \rightarrow MgCl_2(aq) + H_2(g)$$

Table 6.5: The reactivity of different metals with acids

Metal	Reactivity	
Potassium (K)	Most reactive	
Sodium (Na)		
Calcium (Ca)		
Magnesium (Mg)		
Aluminium (Al)		
Zinc (Zn)		
Iron (Fe)		
Tin (Sn)		
Lead (Pb)		
Copper (Cu)		
Silver(Ag)		
Gold (Au)	Least reactive	

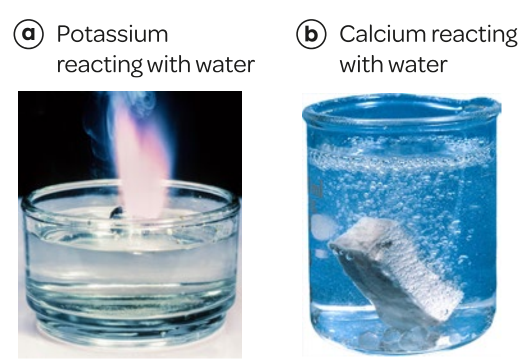


Figure 6.26: Potassium is further up the activity series, indicating it is more reactive than calcium.

Acids react strongly with metal carbonates

A metal **carbonate** is a compound containing a metal cation and the carbonate anion (CO_3^{2-}). Acids react with metal carbonates to form salts, carbon dioxide and water.

Acid + metal carbonate → salt + carbon dioxide + water

For example, calcium carbonate (a compound used to settle an upset stomach) reacts with hydrochloric acid to produce calcium chloride, carbon dioxide gas and water.

Hydrochloric acid	+	calcium carbonate	→	calcium chloride	+	carbon dioxide	+	water
$2HCl(aq)$	+	$CaCO_3(s)$	→	$CaCl_2(aq)$	+	$CO_2(g)$	+	$H_2O(l)$

People burp when they take calcium carbonate to settle an upset stomach. The carbonate reacts with the stomach acids to produce carbon dioxide, which fills up the stomach and has to be released by burping. To test if the gas released in a reaction is carbon dioxide, bubble the gas through limewater. Carbon dioxide turns limewater milky or cloudy.

Figure 6.27: Calcium carbonate reacts with hydrochloric acid to produce calcium chloride and carbon dioxide, which you can see as bubbles.

Acids react readily with metal oxides

A metal oxide is an ionic compound that contains a metal cation and oxide ions (O^{2-}). When acids react with metal oxides, they typically undergo a neutralisation reaction, producing a salt and water. Hydrogen ions (H^+) from the acid combine with the oxide ions (O^{2-}) from the metal oxide to form water (H_2O), while the remaining ions form a salt.

Acid + metal oxide → salt + water

For example, when hydrochloric acid (HCl) reacts with copper(II) oxide (CuO), the products are copper chloride ($CuCl_2$) and water.

Hydrochloric acid + copper(II) oxide → copper chloride + water

2HCl(aq) + CuO(s) → CuCl2(aq) + H2O(l)

Figure 6.28: Copper(II) oxide is a black powder but forms a greenish-blue solution when it reacts with HCl.

This type of reaction is often used to illustrate how acids can neutralise basic compounds, as metal oxides are generally basic in nature. This process not only highlights the principles of acid–base chemistry but also demonstrates practical applications, such as the production of salts in a laboratory setting.

Summary of reactions of acids

As we have seen in this section, acids can react in a number of ways to form neutral products. It is important to be familiar with these reactions, and to be able to predict the products, based on what the acid is reacting with. Table 6.6 is a summary of the reactions of acids.

Table 6.6: Reactions of acids

Reacts with acid to form →	Products
Base (OH–) + acid	Salt + water
Metal + acid	Salt + hydrogen gas (H_2)
Metal carbonate + acid	Salt + water + carbon dioxide
Metal oxide + acid	Salt + water

When experimenting with reactions of acids in the laboratory, it is important to maintain safety at all times. Safety glasses and protective clothing should always be worn, and if the acid is strong and/or concentrated, gloves should be worn to prevent contact with skin. Look for the corrosives pictogram on the container.

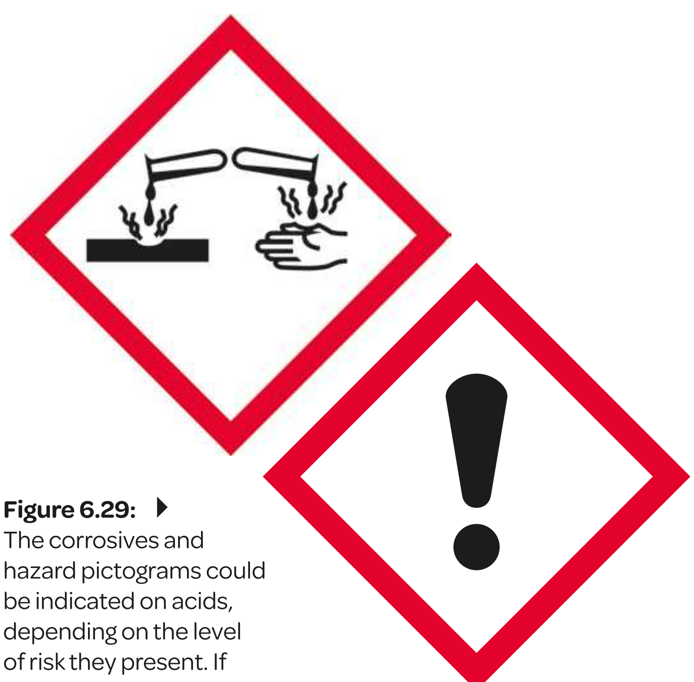


Figure 6.29: ▶ The corrosives and hazard pictograms could be indicated on acids, depending on the level of risk they present. If the acid is labelled with a corrosives pictogram, it is important to wear gloves.

Learning Ladder

Reactions

1. Write the general word equation for an:
   - **a** acid reacting with a base.
   - **b** acid reacting with a metal.
   - **c** acid reacting with a carbonate.
2. Describe what happens when an acid reacts with a metal.
3. **a** Predict the products of a reaction between sulfuric acid and zinc metal.
   b Describe how you could show that the gas formed is *not* carbon dioxide.
4. Write a complete and balanced chemical equation to represent the reaction in Question 3.
5. **a** Discuss how calcium carbonate can help an upset stomach.
   b Conduct a search to explore one way that indicators are used in industry. Share your findings with a classmate.

Conducting investigations

see page 408

1. Identify a hazard present when acids react with metals. Describe two ways to minimise the hazard.
2. Propose two indicators that would be suitable to detect a pH change of between 7 and 9. Describe the observations required for each indicator identified.
3. Read the aim and method for Investigation 6.7A on page 552. Based on the type of data being collected and the results table, propose two errors in the method.
4. Propose modifications to the method that could improve the precision of the results.

In context

Investigate a range of edible indicators such as cherries, blueberries, curry powder, radishes, plums, tomatoes and turnips. Prepare an indicator chart, similar to Figure 6.25, that shows the colour changes that occur at specific pH values for the natural indicators you have explored.

Success criteria

- I can describe what happens when an acid reacts with a base, a metal and a carbonate.
- I can explain how pH indicators are used to measure the pH change of neutralisation reactions.

6·8 ▸ Rate of reaction: collision theory

Learning intention

At the end of this lesson, I will be able to describe the features of a successful collision required for chemical reactions to occur.

Key terms

activation energy: the energy required for successful collisions and a chemical reaction to occur

collision theory: a theory which states that for a chemical reaction to occur, particles must collide with the correct orientation and with enough energy; can be used to predict the rate of reactions

Investigation 6.8A

The effect of concentration on the rate of reaction, page 560

Investigation 6.8B

The effect of temperature on the rate of reaction, page 562

Content group: Rate of chemical reactions

Chemical reactions can occur quickly, such as when a campfire is burning or a missile is being fired, or slowly, such as when milk is spoiling or a ship is rusting. The rate of a chemical reaction is a measure of how quickly the reaction can be completed; that is, the amount of reactants that are converted into products over a certain period of time. The process by which substances react to form new materials depends on particles interacting in specific ways.

Collision theory helps to predict reaction rates

For a reaction to occur, atoms or molecules must collide successfully. Collisions happen between particles all the time, but not all of them are successful. **Collision theory** states that there are two requirements for a successful collision:

- sufficient energy
- correct orientation of molecules.

A collision must occur with enough force to provide the energy required to break the bonds of the reactants so that new bonds are able to form. This is called **activation energy**. Particles must also be positioned in such a way that when a collision occurs, the atoms are aligned properly to allow new products to form, as shown in Figure 6.31.

If the proportion of successful collisions in a given amount of time is high, the rate of the reaction is high. If the proportion is low, the rate of the reaction is low. Both the frequency of collisions and their success rate contribute to the rate of chemical reactions.


Figure 6.30: (a) Wood burning is a fast chemical reaction, which may be completed in a few hours.
(b) Iron rusting is a slow chemical reaction, which can take many years.

Many factors can affect reaction rate

Every chemical reaction makes products from the reactants at a certain rate, but this rate is not fixed. It is affected by:

- concentration
- temperature
- surface area
- catalysts
- pressure
- agitation (stirring).

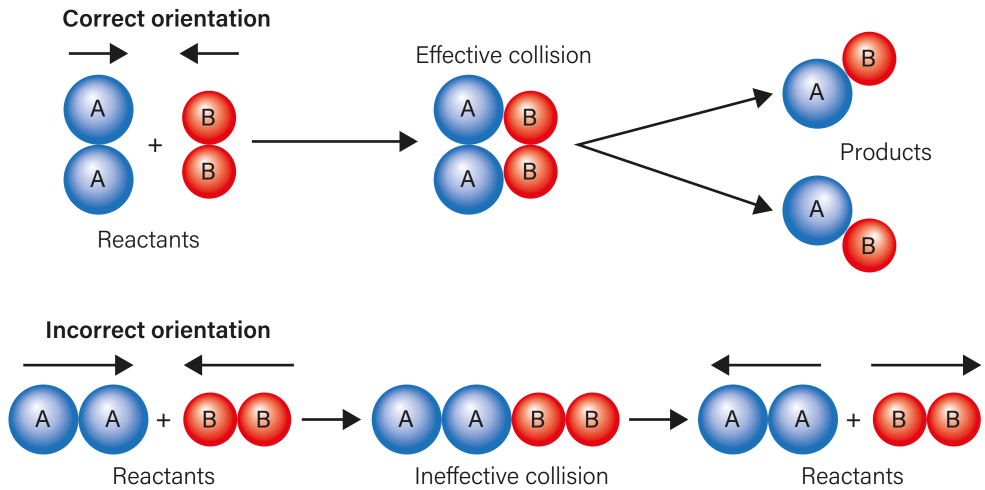


Figure 6.31: Reacting particles must collide with the correct orientation for the collision to be successful.

It is possible to adjust many of these factors, either to reduce the reaction rate to make the reaction safer to handle, or to increase the reaction rate so that products are made more quickly. Increasing the reaction rate is very common in the chemical industry, to reduce costs and maximise profits.

Concentration, temperature, surface area and catalysts will be explored in more detail in the following section.

Learning Ladder

Reactions

1. Identify two things that must occur for a chemical collision to be successful.
2. Propose what would happen to the rate of a reaction if you increased the pressure within a given volume.
3. Justify your response to Question 2 with reference to collision theory.
4. When H^+ and OH^- ions collide with enough force, it might result in a successful collision. Using labelled diagrams, show how the ions would be aligned during a:
   - **a** successful collision.
   - **b** unsuccessful collision.
5. Evaluate the following statement: 'It is always a good thing to increase the rate of a reaction.' Include reference to real-world examples in your evaluation.

Questioning and predicting

see page 401

1. Select the question below that is most suitable to be investigated scientifically:
   - **A** How fast is a reaction between sulfuric acid and:
     - **i** marble chips?
     - **ii** sodium carbonate?
     - **iii** baking powder?
   - **B** How does increasing the concentration of sulfuric acid affect how quickly it reacts with marble chips?
2. Rewrite the scientific question *not* selected in Question 1 so it can be investigated scientifically.
3. Propose a hypothesis for each of the suitable scientific questions from Questions 1 and 2, with reference to collision theory.
4. For the hypotheses you constructed in Question 3, ask yourself the following questions:
   - **a** Did you include the independent and dependent variables, as well as the predicted outcome?
   - **b** Can your hypotheses be tested scientifically in the laboratory?
5. Evaluate your hypotheses in Question 3 based on your responses to Question 4. If you answered 'no' to Question 4a or 4b, adjust your hypotheses to follow the set conventions.

In context

1. Propose why collisions between the reacting particles are important for a chemical reaction to take place.
2. Conduct a search to outline the history of collision theory and how it relates to rates of reactions in industry.

Success criteria

- I can state the two requirements for a successful chemical collision to occur.
- I can describe the rate of a reaction in terms of collision theory.

6·9 ▸ Factors that affect rate of reactions

Learning intention

At the end of this lesson, I will be able to describe how different factors affect the rate of chemical reactions.

Key terms

catalyst: a substance that increases the rate of a chemical reaction without being used up

enzyme: a biological catalyst that increases the rate of reactions in cells

kinetic energy: the energy of movement

surface area: the area of the outermost layer of an object

Investigation 6.9A

The effect of surface area on the rate of reaction, page 563

Investigation 6.9B

The effect of a catalyst on the rate of reaction, page 564

Investigation 6.9C

Student-designed investigation: investigating rate of reactions, page 566

Content group: Rate of chemical reactions

Many factors influence the rate of reaction, including concentration, temperature, surface area and the presence of a catalyst. Temperature and concentration are relatively easy to control. We adjust these factors every day in our kitchens. Catalysts and surface area may require special equipment or materials to control.

Concentrated substances react more quickly

The concentration of a substance is a measure of how many particles are in the volume of a liquid solution or a container of gas. Increasing the concentration of the reactants increases the number of particles within a given volume. The more crowded the particles are, the more collisions occur. When particles collide more frequently, the proportion of successful collisions increases, leading to an increase in the rate of the reaction.

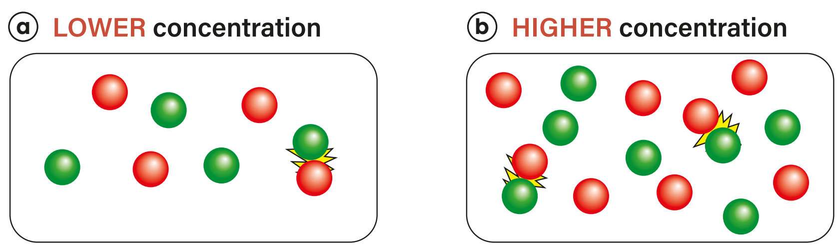


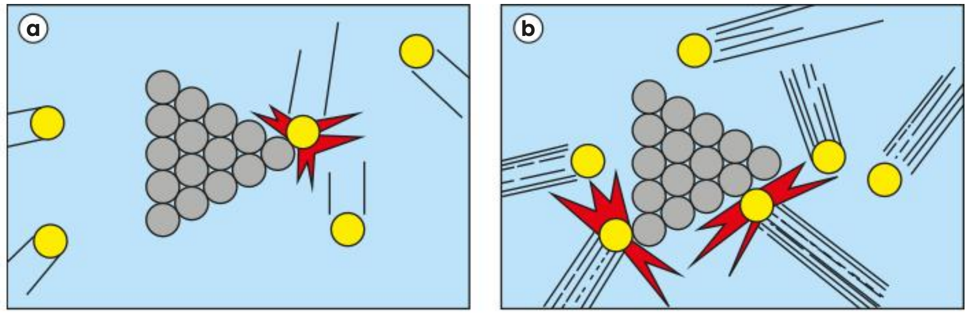
Figure 6.32: (a) Fewer reactants in a specific amount of space will have fewer opportunities to collide in a given amount of time, as the particles are further away from each other. (b) More reactants in the same amount of space will have more successful collisions in the same amount of time, as there are more opportunities for collisions to occur, which will increase the rate of the reaction.

The concentration of a gas can be adjusted by changing the pressure. The pressure of a system increases when the volume of the reactant vessel decreases. This means that there are now the same number of particles in a smaller volume, leading to more collisions between particles.

Figure 6.33: Concentrated sulfuric acid reacts dramatically with sucrose (table sugar).

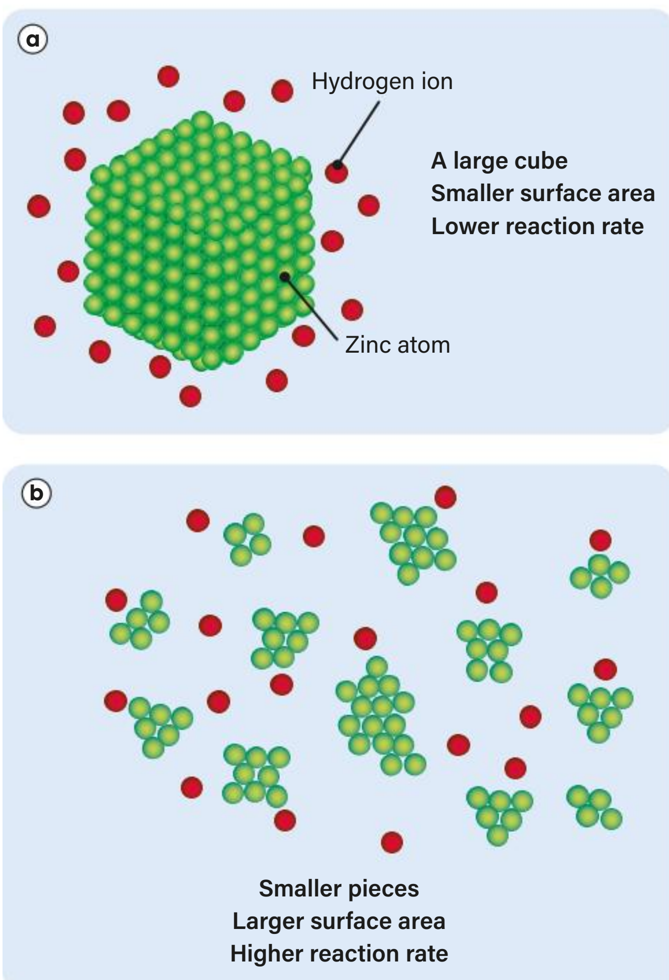
Raising the temperature increases the reaction rate

Increasing the temperature of a system increases the average **kinetic energy** of the particles in the system. As the average kinetic energy increases, the particles move faster, so they collide more frequently and have more energy when they collide.



▲ **Figure 6.34:** Adding heat to a reaction provides the particles with higher levels of kinetic energy. This means they are able to move around more quickly and to collide with more energy. Increased kinetic energy means that the activation energy requirements of the reaction can be reached.

By increasing the temperature of reactants, more particles will have enough energy and collide more often. This means that the hotter the reactants, the faster the reaction. Likewise, the cooler the reactants, the slower the reaction.



▲ **Figure 6.35:** (a) Hydrogen ions from the acid can collide only with the outer layer of zinc atoms of the large cube of zinc. The reaction rate is slow. (b) When the zinc block is broken into smaller pieces, more surface is exposed for the hydrogen ions to collide with and the rate of the reaction increases.

We change temperature to adjust reaction rates every day. You boil water before making a cup of tea because the tea dissolves faster in hot water. If you make a cup of tea with water at room temperature, it will take much longer for the tea to flavour the water. Similarly, we keep food in the refrigerator to slow down chemical reactions that cause it to spoil over time.

Increasing the surface area increases the reaction rate

Surface area is the exposed area of a solid substance. If you increase the surface area of a substance, there are more particles at the surface that have the opportunity to react with another substance, so the reaction rate increases.

Consider the reaction of zinc metal with an acid (Figure 6.35). If the zinc is in the form of a large cube, the total surface area of the cube is the sum of the areas of the faces of the cube. If the zinc cube is broken up into many smaller pieces, the total surface area greatly increases, and more area is exposed to react with the acid. If the zinc is crushed into a powder, its surface area increases even further. This form of zinc reacts the fastest.

Small pieces of food cook faster than larger pieces. These smaller pieces of food have a large surface area (compared to their volume) exposed to heat. When you take tablets or pills, different tablets are digested at different rates, depending on their surface areas.

Catalysts increase the rate of reaction

A **catalyst** is a substance that increases the rate of a chemical reaction without being used up itself. When writing a chemical equation, we often write the name of the catalyst above the reaction arrow; this indicates its presence but also its lack of involvement in the reaction itself.

Catalysts lower the activation energy of a reaction, which is the energy required to start a reaction. This enables the reaction to occur at a lower temperature.

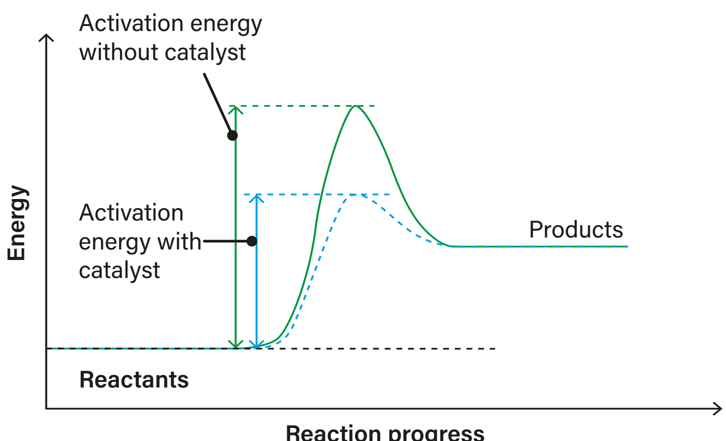


Figure 6.36: Adding a catalyst to a chemical reaction lowers the activation energy of the reaction. More collisions will have enough energy to overcome the smaller energy barrier.

Catalysts are specific, which means that a catalyst increases the rate of some reactions but not others. Catalysts are important in industry because they reduce reaction times and enable chemical processes to take place at lower temperatures and pressures. Therefore, they reduce the cost of production of valuable products.

Enzymes are biological catalysts. They are proteins that help speed up chemical reactions in the body. For example, amylase in saliva catalyses the breakdown of carbohydrates in your mouth.

Here are some common uses of catalysts.

- Catalytic converters in cars contain platinum, which catalyses the conversion of toxic carbon monoxide into carbon dioxide.
- Biological catalysts in detergents remove protein stains, such as egg yolk, which are otherwise hard to dislodge.
- Catalysts in the paper industry break down paper pulp to produce smooth paper for magazines.
- Catalysts turn milk into yoghurt and petroleum into plastic milk jugs, CDs and bicycle helmets.

Figure 6.37: Saliva contains enzymes that start the chemical reactions of digestion.

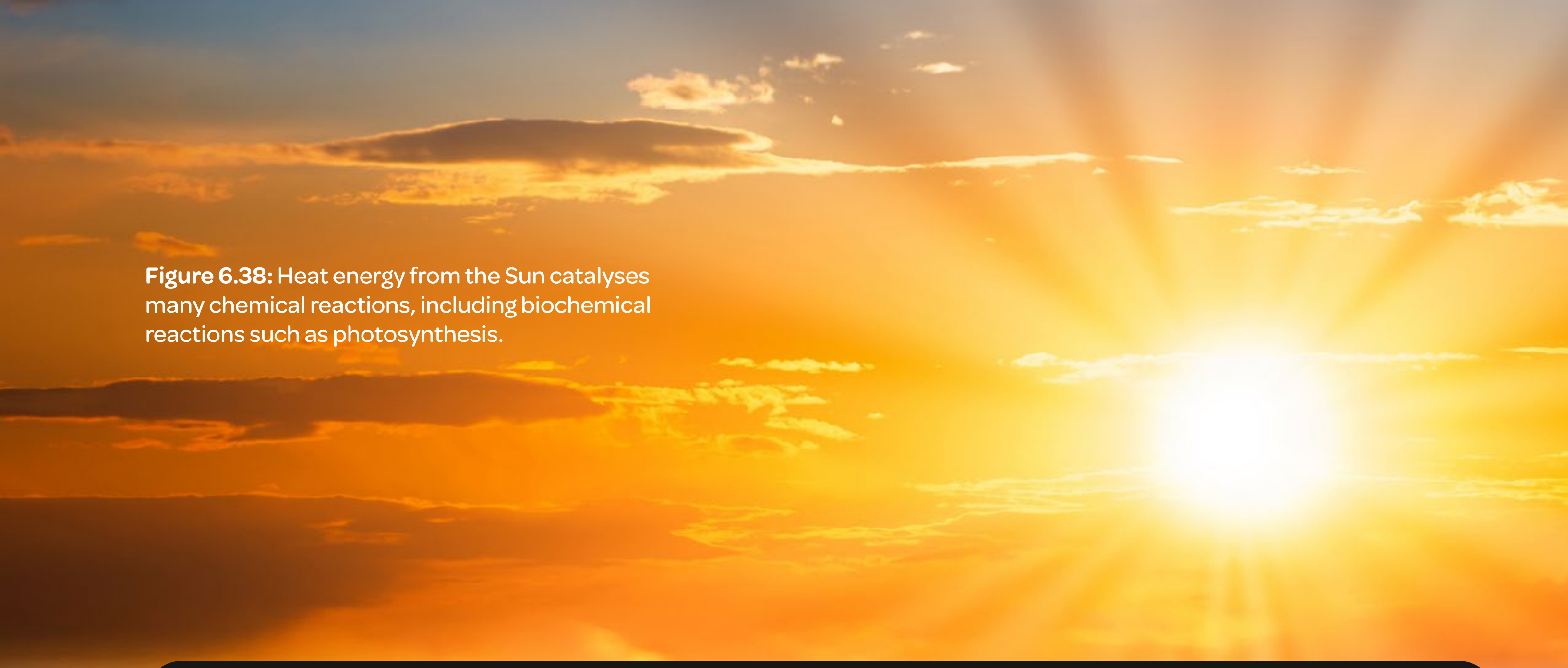


Figure 6.38: Heat energy from the Sun catalyses many chemical reactions, including biochemical reactions such as photosynthesis.

Learning Ladder

Reactions

1. Identify the following statements as true or false.
   - **A** A crushed substance has a large surface area.
   - **B** Diluting an acid with water will make it react faster with baking soda.
   - **C** Decreasing the volume of a reaction container of gas will decrease the rate of reaction.
   - **D** Stirring oats and water over heat will cook porridge faster than without stirring.
2. Describe two things you could do to decrease how long it takes to cook vegetables.
3. Explain:
   - **a** how temperature increases the rate of a chemical reaction.
   - **b** how surface area influences the rate of chemical reactions.
   - **c** what a catalyst is and give an example of one.
   - **d** how enzymes are a type of catalyst.
4. Sunlight is a catalyst for the breakdown of hydrogen peroxide into hydrogen gas and oxygen gas. Write a word equation to represent this reaction, remembering that a catalyst is not used up in a reaction.
5. Research why reaction rate needs to be controlled in industry. What compromises are made regarding temperature and concentration, and why?

Planning investigations

see page 405

You wish to investigate whether a whole or a crushed tablet of antacid eases symptoms of heartburn the fastest.

1. Performing tests on animals (including humans) poses a high risk. Propose how you can eliminate this as a risk when planning your investigation. (Hint: Stomach acid that causes heartburn is primarily hydrochloric acid.)
2. Identify the independent and dependent variables, as well as any variables that need to be controlled. (More information on variables is available in the Science how-to section on s 401–4.)
3. Formulate an aim for this investigation that considers a wider context.
4. Summarise the method you could follow to address the aim of the investigation. Be sure to consider ethics, reliability and validity. (More information on ethics, reliability and validity is available in the Science how-to section on pages 423–34.)
5. Evaluate the selection of the dependent variable for this investigation. Propose two other ways you could measure the effectiveness of antacid tablets.

In context

1. Why and how are catalysts important in our lives?
2. - **a** Research catalysts in industry. Identify a catalyst and state where it is used.
   - **b** How does this catalyst help to improve the rate of this reaction?
   - **c** Write the word and chemical equations for the reactions that take place.
   - **d** What would happen if this catalyst was not used in the reaction?

Success criteria

- I can describe the effect of temperature, concentration, surface area and catalysts on the rate of some common chemical reactions.
- I can explain how factors affect the rate of reactions, with reference to collision theory.

6·10 ► Nuclear reactions and the big bang

Learning intention

At the end of this lesson, I will be able to explain how nuclear reactions are different from chemical reactions, and outline how the first elements were formed after the big bang.

Key terms

antimatter: particles that have properties opposite to that of normal matter

big bang theory: the theory which states that the universe began as a single point that expanded and is still expanding

nuclear reaction: a reaction that involves the nucleus of atoms

plasma: superheated matter consisting of ionised gas

redshift: a change in light's wavelength towards the red end of the visible spectrum

singularity: a small dense region of space containing matter

Investigation 6.10

Modelling the expanding universe, page 568

Content group: Nuclear reactions

As technology has improved, and more observations and data have been gained, our understanding of the universe and how it formed has changed. The big bang theory is how scientists currently think the universe was formed – the universe rapidly expanded from a dense singularity about 13.7 billion years ago, producing matter and forming elements through nuclear reactions, that then went on to create stars and galaxies.

Nuclear reactions are different from chemical reactions

Chemical reactions usually involve chemical changes such as the rearranging of atoms to make new substances, and these reactions usually involve the electrons of atoms. **Nuclear reactions** are different from chemical reactions because they involve a change in the nucleus of an atom, and usually produce new elements. Nuclear reactions involve changes to the protons (p) and neutrons (n) in the atom's nucleus.

One type of nuclear reaction is when two nuclei of atoms join to form a new element. For example, in Figure 6.39a, two hydrogen atoms join to make a helium atom; in the process, they release energy.

Another type of nuclear reaction is when the nucleus of a large and heavy element with many protons and neutrons splits to form other smaller elements. For example, in Figure 6.39, the nucleus of uranium is split by bombarding it with neutrons that start the nuclear reaction. New elements (krypton and barium) are formed, and neutrons and energy are released.

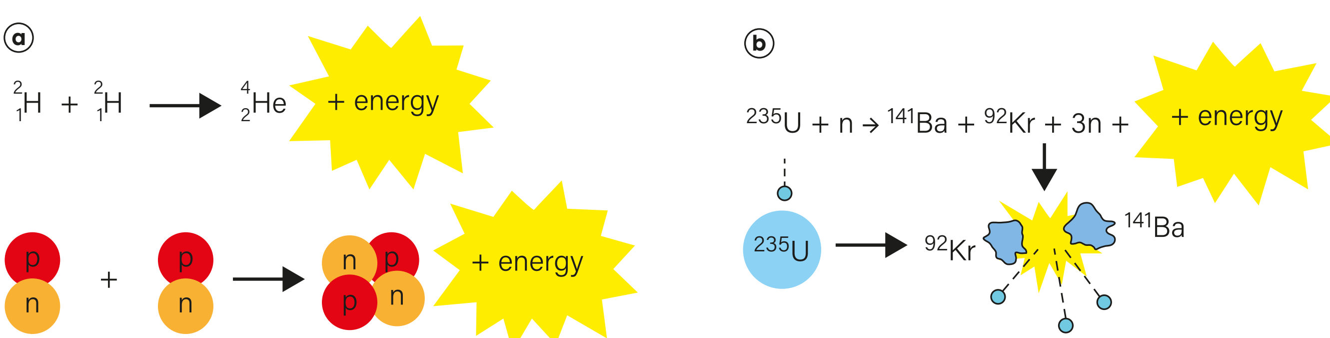
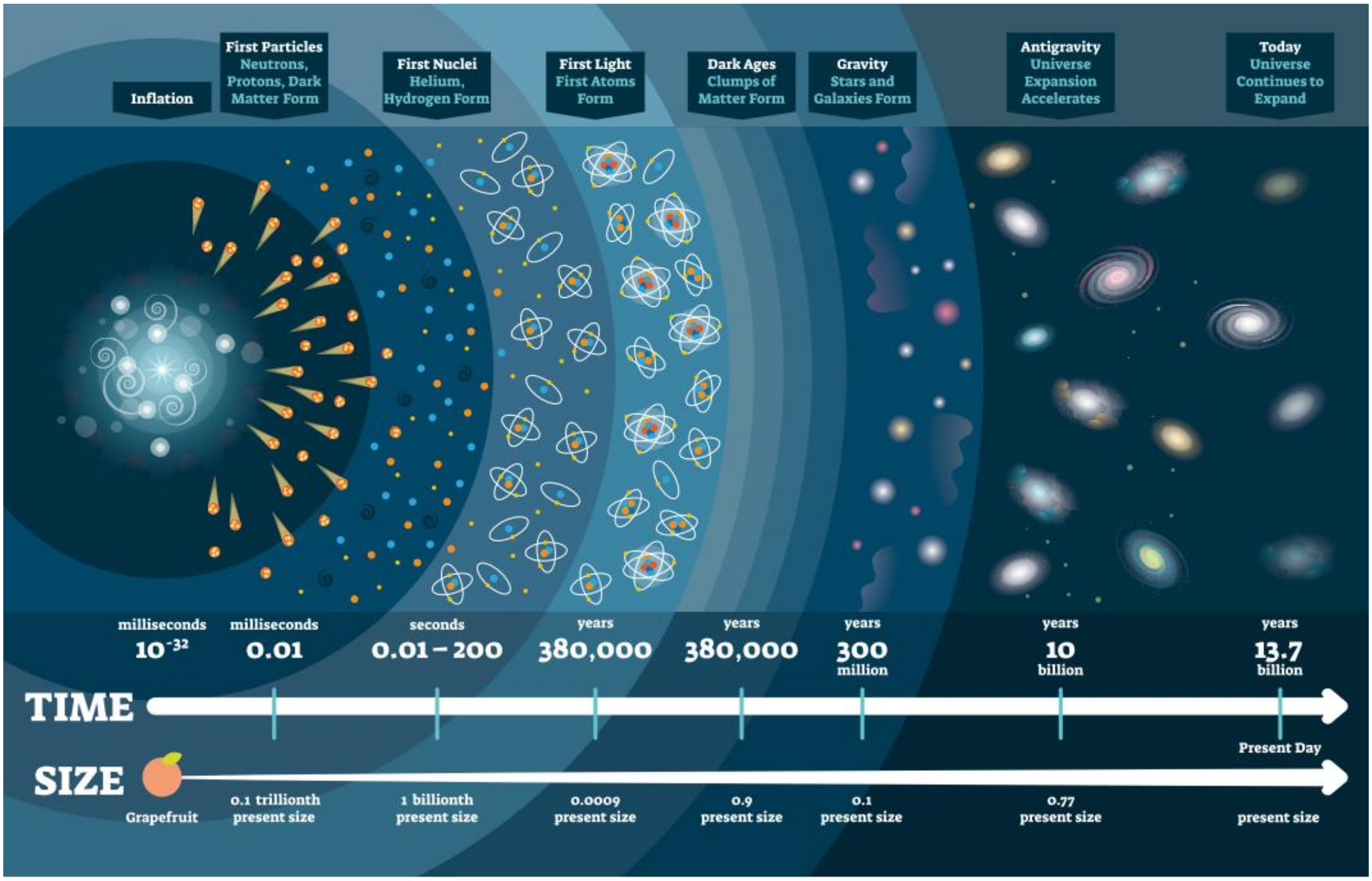


Figure 6.39: Two examples of nuclear reactions.
(a) Hydrogen atoms combine to form a new helium atom.
(b) Uranium is split into smaller elements.



▲ **Figure 6.40:** The big bang timeline, showing when elements were formed.

The universe began as a singularity

The **big bang theory** states that the universe began about 13.7 billion years ago as a small, dense region called a **singularity**, which then rapidly expanded. This expansion is the 'big bang'. After the big bang, the first events happened very quickly.

- As it continued to expand, the universe started to cool, allowing the formation of particles of matter and **antimatter** (particles that are the opposite of matter).
- At about 0.001 seconds after the big bang, these particles annihilated each other. The matter that we observe today is what is left over from this interaction.
- After 3 minutes, the protons and neutrons combined in nuclear reactions (as in Figure 6.39a) to form the nuclei of atoms, about 75 per cent hydrogen, 25 per cent helium, and a small fraction of lithium. At this stage, all the matter and energy that would ever exist was formed, and all in the time it takes to boil a kettle.
- Between the formation of these nuclei and 500 000 years, the universe was a **plasma** of hydrogen, helium and lithium nuclei and free electrons (electrons not attached to atoms).
- At about 380 000 years, the universe cooled enough for the nuclei to attract electrons and to form atoms, which released light energy.
- The first stars and galaxies then began to form 1 billion years after the big bang.

There are three main pieces of evidence for the big bang

The universe is expanding

Edwin Hubble observed that light coming from distant galaxies was stretched into longer wavelengths: it was **redshifted**. This indicated that galaxies are moving away from us and the universe is expanding. The movements of the galaxies can be traced back to a single point, meaning that the universe must have once been contained in a small region of space.

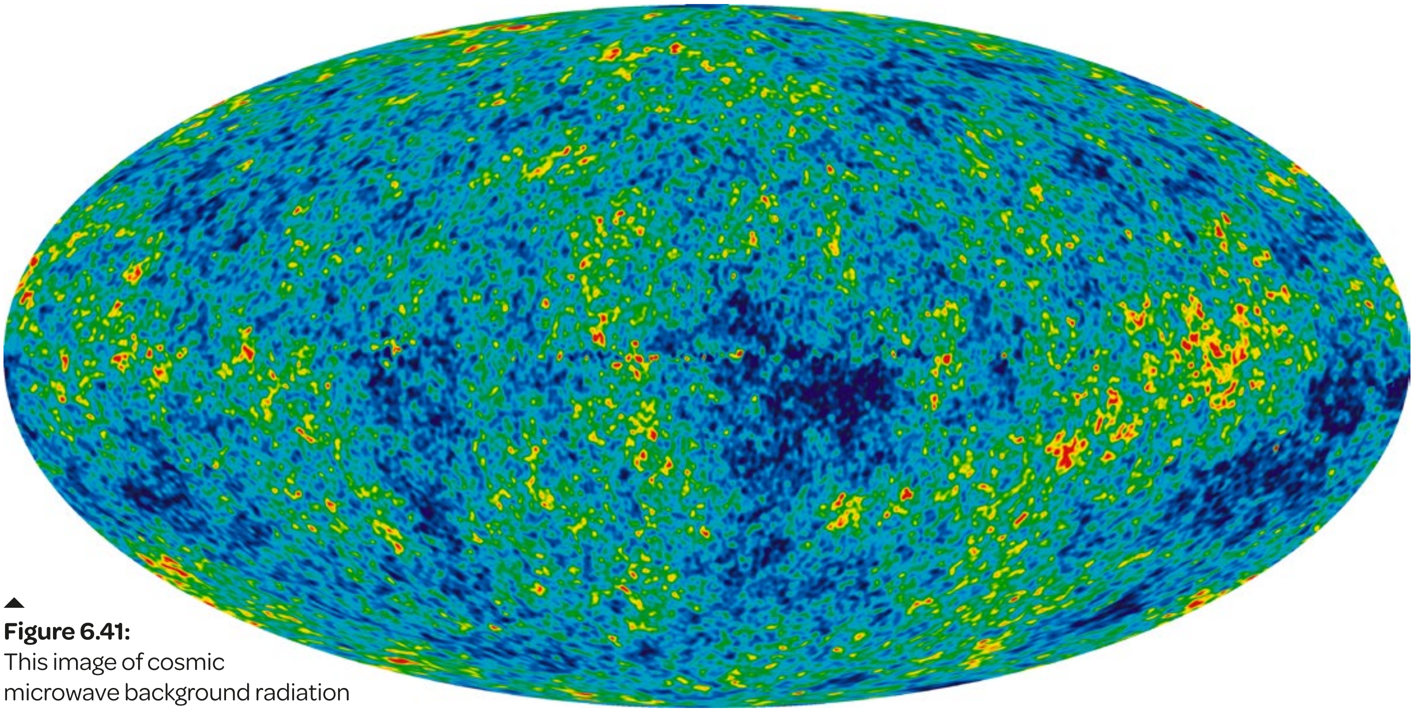


Figure 6.41: This image of cosmic microwave background radiation was taken from the Wilkinson Microwave Anisotropy Probe and shows clumping of matter.

Abundance of light elements

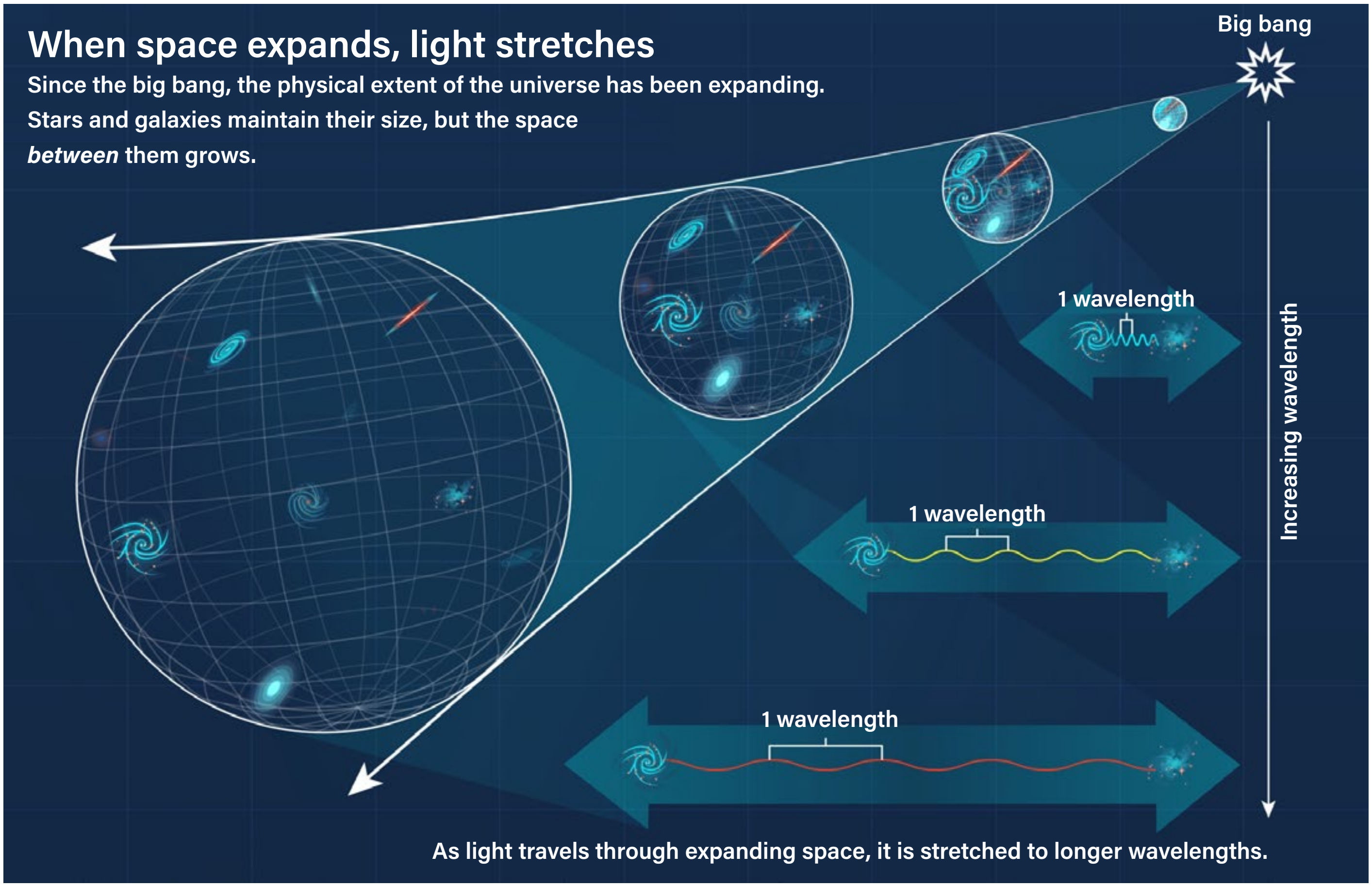
The universe is about 74 per cent hydrogen and 24 per cent helium by mass, with the other 2 per cent being all the other heavier elements in the periodic table. This abundance supports the big bang theory because if helium had not been made by the big bang and was only made by fusion in stars, there would be significantly less than 24 per cent.

Cosmic microwave background radiation

Cosmic microwave background radiation is leftover heat released about 100 000 years after the big bang, when the universe had cooled enough to allow electromagnetic radiation to pass through it. Because the universe was not of uniform density when the cosmic microwave background was released, images show 'clumps' of matter. The cosmic microwave background would have originally been released as visible and ultraviolet light, but the expansion of the universe has redshifted it into the microwave band.

Current observations and calculations put the age of the universe at 13.7 billion years. The Hubble Space Telescope measured how far away galaxies were from us and the speed at which they were moving. The telescope was also used to calculate the ages of the oldest star clusters – the first stars that would have formed after the big bang. This allowed astrophysicists to calculate how long it took galaxies to reach their current locations and thus to estimate the age of the universe.

Figure 6.42: The Hubble Space Telescope has been a key tool used by scientists in measuring the age of the universe.



▲ **Figure 6.43:** Light from distant galaxies is redshifted.

Learning Ladder

Reactions

1. Identify and describe an example of a nuclear reaction.
2. Describe the difference between chemical and nuclear reactions by outlining the type of changes that occur in each reaction.
3. In a nuclear reaction, apart from new atoms forming, outline what else may be needed to start a reaction or what may be released during a reaction.
4. Apply your knowledge of nuclear reactions to describe how the big bang caused the creation of elements.
5. Analyse how our understanding of the big bang theory relates to our knowledge of how elements formed.

Observing

see page 398

1. Identify some of the tools that scientists have used to investigate the big bang.
2. Look at Figure 6.40 and consider the time taken for the big bang to occur. Describe how you think scientists could estimate measurements of the time taken for early stages of the big bang, when it occurred 13.7 billion years ago.
3. Look at Figure 6.40 and make an inference about what may occur in future.
4. Describe the types of observations that scientists have used to estimate the age of the universe.
5. Use secondary research to identify one telescope used to investigate the big bang and explain what it measured.

In context

Construct a timeline of major findings that helped us to understand how the universe formed.

Success criteria

- I can explain how nuclear reactions are different from chemical reactions.
- I can outline how the first elements were formed after the big bang.

6·11 ▶ Radioactive isotopes

Learning intention

At the end of this lesson, I will be able to explain why radioactive isotopes are unstable and how they decay.

Key terms

alpha particle: a particle made of two protons and two neutrons

atomic number: the number of protons in an atom

beta particle: a high-energy, high-speed electron

gamma radiation: high-energy electromagnetic waves

ionise: to remove electrons from an atom or molecule

isotopes: atoms of the same element with the same number of protons but a different number of neutrons

penetrating power: how well radiation from radioactive materials can pass through matter

radioisotope: an isotope that emits radiation

Content group: Nuclear reactions

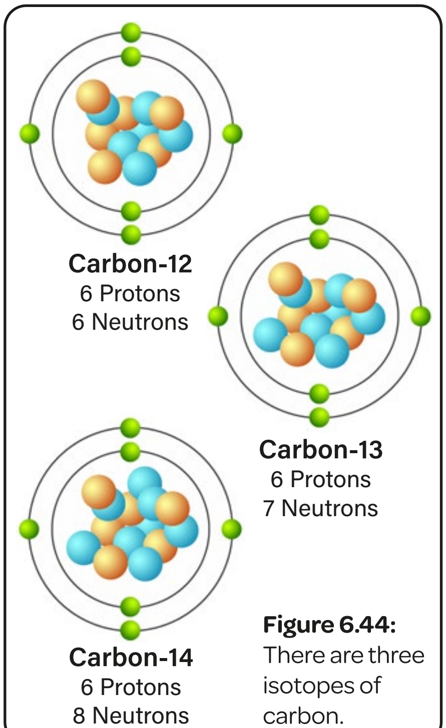


Figure 6.44: There are three isotopes of carbon.

Some atoms are unstable because their nuclei contain too many neutrons or protons. The nucleus breaks down (or decays) and releases particles and energy, while the atom is transformed into a new element. The emissions are known as radiation and can be alpha particles, beta particles or gamma rays.

Radioisotopes are unstable atoms that decay

Atoms of the same element always have the same number of protons. An **isotope** of an element has the same number of protons but a different number of neutrons. Isotopes have the same **atomic number** but a different atomic mass because the number of neutrons is different. For example, carbon has three isotopes (Figure 6.44). Carbon-12 has six protons and six neutrons. Carbon-14 has six protons and eight neutrons. Carbon-14 has a higher atomic mass because of the extra neutrons.

Most atoms have stable nuclei, with a balanced number of protons and neutrons. Too many protons or neutrons creates too much energy in the nucleus. These unstable atoms are known as **radioisotopes**.

An unstable nucleus emits alpha or beta particles

When a nucleus has too many protons, the nucleus breaks down and releases energy and an **alpha particle**, which is made up of two protons and two neutrons and is a type of radiation (alpha radiation). When an alpha particle is released, a new element is also formed, with an atomic number two less than the original element.

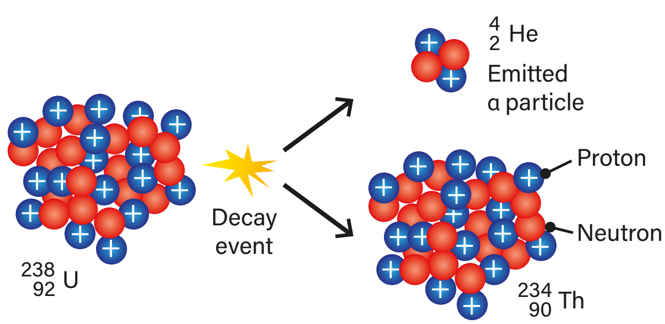


Figure 6.45: Uranium-238 has too many protons and is unstable. Therefore, it decays by emitting alpha radiation to become a new element, thorium-234.

When a nucleus has too many neutrons, a neutron breaks down into a proton and an electron. The proton is retained in the nucleus, and the electron is emitted as beta radiation. Because the element now has an additional proton, the atomic number increases by one, producing a new element (Figure 6.41). Another type of radiation that is produced when a nucleus decays is **gamma radiation**. Gamma rays are high-energy radiation.

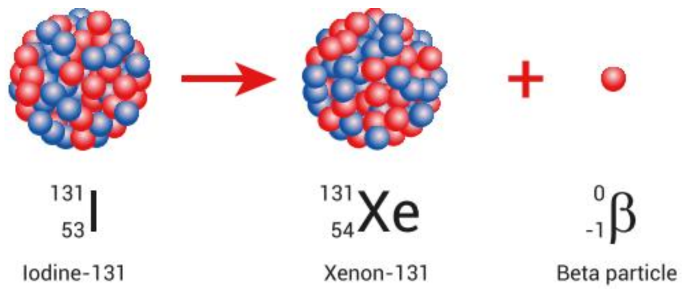


Figure 6.46: Iodine has too many neutrons and is unstable. Therefore, it decays by producing a proton and emitting beta radiation. The proton is retained in the nucleus, increasing the atomic number and creating a new element: xenon.

Different types of radiation have different properties

Because they have a large positive charge, alpha particles **ionise** (draw) electrons away from other atoms. However, they have a low **penetrating power** because they lose energy each time they ionise an atom. Alpha particles can be absorbed by paper.

Beta particles ionise atoms that they pass through, but not as strongly as alpha particles do; however, they are more likely to penetrate other atoms. Beta particles can pass through paper but are absorbed by substances such as aluminium.

Gamma rays are emitted when the protons and neutrons in an unstable nucleus rearrange and emit energy instead of a particle. Gamma rays are high-energy electromagnetic waves, not particles, and have no mass or charge. Gamma rays are more penetrating than alpha or beta radiation and can pass through many materials. They are absorbed by lead because it is very dense (Figure 6.47).

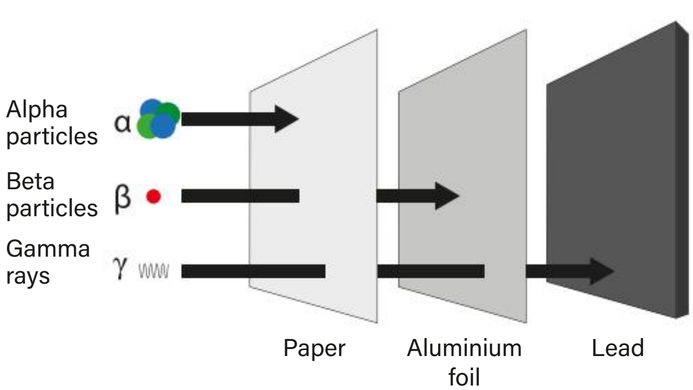


Figure 6.47: Different types of radiation have different penetrative powers.

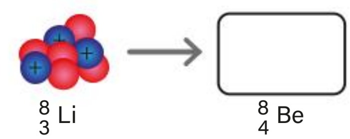
Table 6.7: Summary of radiation types

Particle	Symbol	Contains	Charge
Alpha	α	2 protons and 2 neutrons	+2
Beta	β	Electron	–1
Gamma	γ	High-energy electro-magnetic radiation	0

Learning Ladder

Reactions

1. Identify the three types of radiation emitted in a nuclear reaction. What are they composed of?
2. Using an example, describe the changes that occur in a nucleus when alpha radiation is produced from an unstable isotope.
3. Explain what must be different in the nucleus of an atom for it to release beta or alpha radiation.
4. Lithium-8 is an unstable isotope of lithium. It decays by emitting beta radiation to form a new element, beryllium-8. Copy and complete the diagram to show the structure of the beryllium atom formed.



5. Propose how the penetrating power of different types of radiation can be used in industry.

Planning investigations

see page 405

1. If you were undertaking investigations using radioactive material, describe at least two ways you could reduce the risks of using radiation.
2. Review Figure 6.47. Identify the controlled variables, dependent variable and independent variable you would use to investigate the penetrative power of different types of radiation.
3. Construct an aim for that investigation.
4. Design a brief method for your investigation.
5. Construct a results table for your investigation that shows the type of data you could collect. Consider the units that you may use to measure your variables.

In context

Select one type of radiation and summarise one use it has that is important to society.

Success criteria

- I can explain why radioactive isotopes are unstable.
- I can represent nuclear decay as alpha and beta reactions.

6.12 ▸ Half-life of radioactive isotopes

Learning intention

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

- describe the half-life of radioactive isotopes, and outline how this can be used
- identify that the half-life of a radioactive isotope is the time taken for half of the atoms in a sample to undergo radioactive decay
- construct a graph representing the half-life of a radioactive isotope.

Key term

half-life: the time for half of a sample of radioactive isotopes to decay

Investigation 6.12

Half-life coin experiment, page 570

Content group: Nuclear reactions

The half-life of a radioactive substance can tell us the amount of time the substance may be dangerous for and the age of a fossil or an artefact.

Half-life is how long half a sample of radioactive material takes to decay

When a sample of a radioisotope breaks down (or decays), it emits radiation. Over time, the level of radioactivity falls as the amount of radioisotope in the sample decreases. The **half-life** of a radioactive substance is the amount of time it takes for half of the radioactive isotopes in a sample to decay (Figure 6.48). Half-lives range from a fraction of a second to thousands of years, depending on the radioactive isotope and how unstable it is.

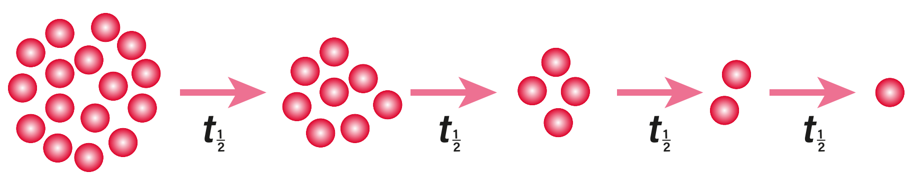


Figure 6.48: In each half-life ($t_{1/2}$), the amount of radioisotope in the sample is halved until all isotopes have decayed.

Radioisotopes have different half-lives and uses

Table 6.8 lists some radioisotopes and their uses.

Table 6.8: Half-life and common uses of some isotopes

Isotope	Half-life	Common uses
Uranium-238	4.47 billion years	Geological dating
Uranium-235	703 million years	Geological dating
Carbon-14	5730 years	Carbon dating
Cobalt-60	5.27 years	Radiotherapy to treat cancer
Yttrium-90	2.67 days	Radiotherapy
Sodium-24	15 hours	Detecting blockages in blood vessels
Fluorine-18	109 minutes	PET imaging for imaging the body

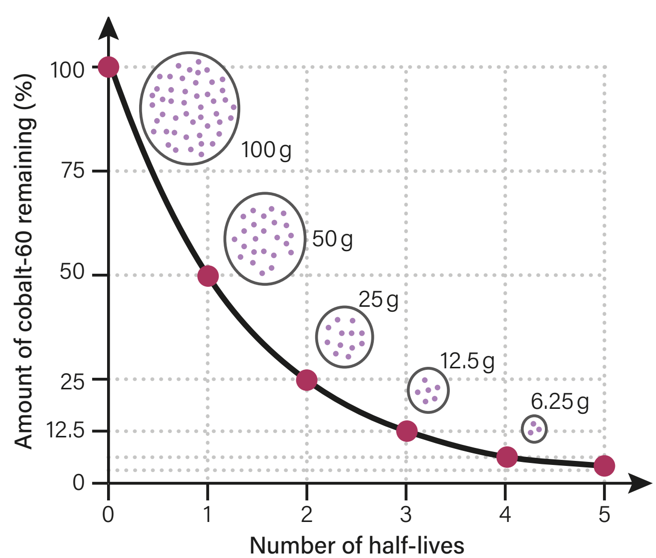


Figure 6.49: The decay curve for cobalt-60, which has a half-life of 5.27 years, shows that it would take about 5 half-lives for all unstable isotopes to decay.

Radioactive dating uses the half-life

Carbon-14 is commonly used to work out the age of substances that contained organic matter. This is possible because all living things are made of common carbon-based molecules.

Carbon-14 is formed in Earth's atmosphere when cosmic rays produce neutrons that cause a nuclear reaction with a nitrogen atom (Figure 6.50). Carbon-14 then combines with oxygen to form carbon dioxide. As plants photosynthesise, they absorb carbon dioxide that contains carbon-14. The carbon-14 enters the carbon cycle and ends up in all living things.

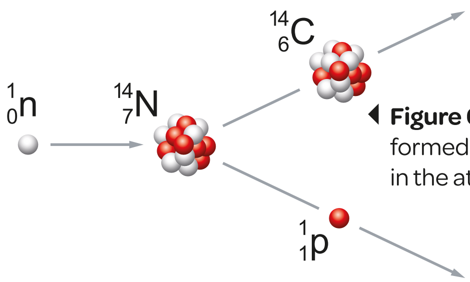


Figure 6.50: Carbon-14 is formed in nuclear reactions in the atmosphere.

In living things, carbon-14 decays (to form nitrogen and beta radiation) and is replaced so that the amount stays constant. But after death, carbon-14 is not replaced once it decays, so the amount reduces. By measuring the amount of carbon-14, we can work out how old a substance is. For example, the half-life of carbon-14 is 5730 years. So, after 5730 years, only half of the initial carbon-14 remains, after 11 460 years a quarter remains, and after 17 190 years an eighth remains. Carbon dating works only on carbon-based material up to 62 000 years old, because by then no carbon-14 is left in the sample.

Carbon-14 is measured using an accelerator mass spectrometer. This accelerates the carbon sample in a magnetic ring. As carbon-14 is heavier than carbon-12 and carbon-13, the carbon-14 travels in a wider circle and is separated from the other isotopes. Carbon-14 atoms can then be counted when they hit a detector.

Figure 6.51: Carbon-14 is used to date carbon-based things that are up to 62 000 years old.

Learning Ladder

Reactions

1. **a** Define 'half-life'.
   b Identify the type of reaction that occurs when carbon-14 decays.
   c Identify the half-life of carbon-14.
2. When carbon-14 decays, it produces beta radiation and nitrogen. Construct a diagram like the one in Figure 6.46 for iodine to describe this reaction.
3. Look at the two uranium isotopes in Table 6.8. Explain which one is more stable and justify your answer.
4. Radioactive dating using carbon-14 identified a boomerang as being approximately 46 000 years old. Calculate approximately how many half-lives have passed since the boomerang was constructed.
5. Propose why radiocarbon dating is important in scientific investigations.

Observing

see page 398

1. Figure 6.50 outlines how an accelerating mass spectrometer separates carbon isotopes. Read the caption and draw a diagram showing the path the three carbon isotopes would travel in the spectrometer as they are separated.
2. Construct a table to predict the age of a sample using cobalt-60, showing the number of half-lives and the time that has passed.
3. Yttrium-90 is used in radiotherapy. A hospital received a sample of yttrium-90, but it could not be used for 20 days. Justify whether the sample would still be suitable for use in treating a patient at the end of the 20-day waiting period.
4. Strontium-90 has a half-life of 28.9 years. It emits beta particles, which can be dangerous for human health. How many years must pass before its activity falls to one-eighth of its original value?
5. Postwar nuclear testing added carbon-14 to the atmosphere. Propose how this may affect the precision of radioactive dating using carbon-14.

In context

Research the carbon-14 radioisotope and how scientists have used it to estimate the ages of many of the mummified bodies that have been discovered in the past century.

Success criteria

- I can describe the half-life of radioactive isotopes.
- I can outline how half-life can be used in scientific dating.

6·13 ▸ Uses of radioisotopes

Learning intention

At the end of this lesson, I will be able to outline uses of radioisotopes and evaluate the benefits and considerations of these uses.

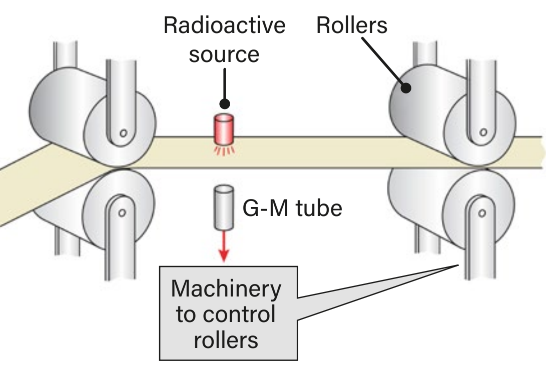
Key terms

radioactive tracer: a radioisotope used to track or trace the path of a substance

radiopharmaceutical: a drug with a radioisotope attached

radiotherapy: a therapy that uses radiation to kill cancerous cells

Content group: Nuclear reactions



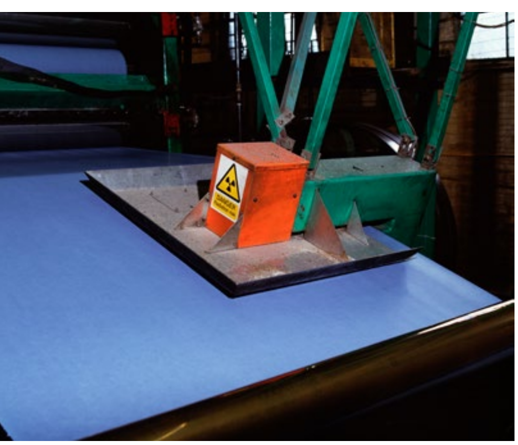


Figure 6.52: Radiation is used to measure the thickness of paper during production. The paper thickness gauge emits beta radiation, which the paper absorbs. By measuring the proportion of radioactive particles that go through the paper, we can calculate its thickness.

Nuclear reactions release energy in the form of radiation, which can be used in many ways. In industry, nuclear reactions are used to produce electricity and in environmental monitoring. In medicine, radiation can be used to treat and diagnose medical conditions. There are many benefits associated with the use of nuclear energy that would not be possible to achieve with other technologies.

Nuclear energy has many industrial uses

Radiation is commonly used in industry to sterilise food in order to extend its shelf life, to check for cracks in underground pipes, and to check the thickness of paper or other material such as metal sheets during manufacturing.

Just as X-rays make images of structures inside the body, industrial gamma-ray imaging (or gamma radiography) allows us to see inside structures such as gas pipelines, concrete and metal welds. We can check for structural issues such as cracks, and confirm that joins are properly welded together. For example, gamma-ray imaging is used to check for structural cracks in metal parts of jet engines on aeroplanes.

Portable gauges to take measurements are also used in agriculture, construction and engineering. They may be used to determine the degree of soil compaction on farmland, or the density of asphalt for a road surface. How far the radiation penetrates the material helps to show how dense it is or whether there are gaps in a structure.

A further use of radioisotopes is in fluid science; for example, **radioactive tracers** in liquids can be used to check for leaks, to measure speed of flow, and to measure the wear of parts in engines. Nuclear energy can also be used to generate electricity.

Nuclear energy is used in medicine

Radiation is used to diagnose medical problems and to treat cancer and other conditions. Usually, **radiopharmaceuticals** are used, which are drugs with a radioisotope attached. In nuclear imaging, radiopharmaceuticals are given orally, injected or inhaled, and are absorbed into the bloodstream. As they travel around the body, they build up in hot spots. The higher radiation of the hot spots is detected by the radiation detector, and indicates that there may be a tumour, an infection or other disease. There may also be cold spots, where there is lack of radiation. Cold spots can indicate a lack of blood flow or a blocked artery.

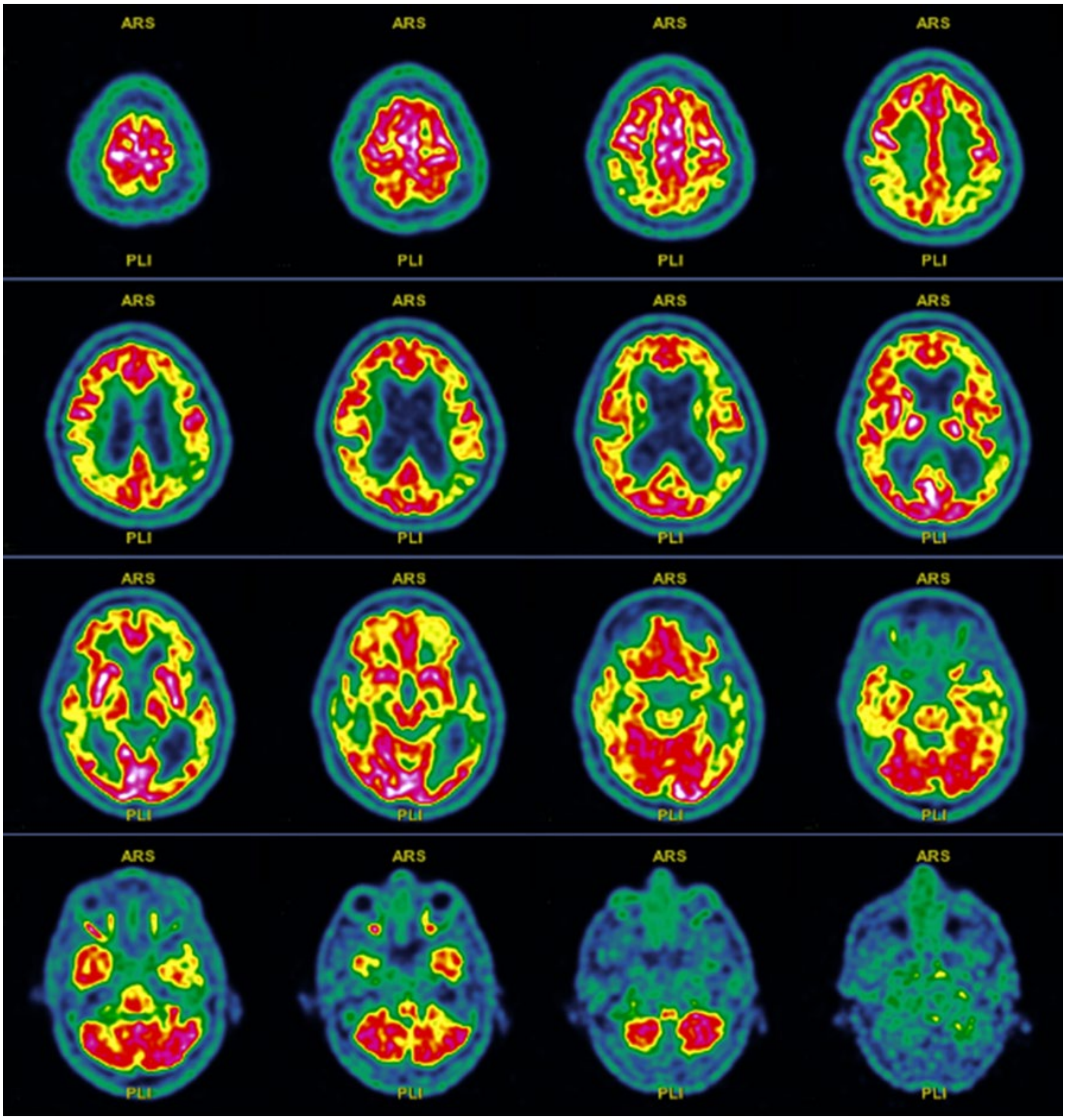


Figure 6.53: During a PET scan, a patient is injected with the medical isotope technetium-99m. The isotope circulates in the bloodstream, emitting gamma radiation, which is detected by the PET scanner. The colour represents a scale from blue (inactive/low activity) to red (high activity).

A positron emission tomography (PET) scan uses a radioactive isotope to produce gamma rays inside the body. Nuclear imaging does not make high-quality, clear images of the body, but it shows where certain parts of it are working well or not or are damaged. There are some advantages, though; nuclear images can show a cancer forming up to two years before X-rays could detect it.

The use of radiation to treat cancer is known as **radiotherapy**. Radiation can destroy the tumour and eliminate the cancer. Radiation may stop a tumour from growing, but it can also damage the surrounding healthy cells and cause side effects such as nausea, swelling, skin irritation, ulcers, hair loss and, in some cases, secondary tumours.

Nuclear energy is used in environmental monitoring

As in industry, environmental monitoring uses radioisotopes to check for leaks in pipes to avoid environmental disasters. There are many other uses of radioisotopes in monitoring the environment. Gold-198 and hydrogen-3 are used to study sewage and liquid waste movements. Gold-194 can be used to trace factory waste that may be causing ocean pollution, and to trace sand movement in river beds and on ocean floors.

The heavy metals zinc-59 and manganese-94 are used to predict where heavy metals may travel in the environment, to help plan how to prevent and clean up heavy metal pollution.

Further, naturally occurring radioisotopes that are already in nature are used to measure environmental factors. For example, tritium, H-3, can be used to measure groundwater up to 30 years old because it has a half-life of 12.3 years, whereas chlorine-36, with a half-life of 301 000 years, can be used to measure the age of water up to 2 million years.

Table 6.9: Some radioisotopes and their uses

Radioisotope	Use	Half-life
Carbon-14	To measure the age of underground water up to 50 000 years	5730 years
Americium-241	In gauges, to measure thickness; and for use in smoke detectors	432 years
Cobalt-60	To sterilise food; and in gamma radiography	5.27 years
Iridium-192	In gamma radiography, to image; and to identify faults in metal	73.8 days
Ytterbium-168	In gamma radiography	32.03 days
Gold-198	To study sewage and liquid waste movement; and for use in and to trace that is factory waste causing ocean pollution	2.7 days
Technetium-99	To image the brain, thyroid, lungs, spleen, liver, kidneys, bones, heart and blood; and to detect infection	65.94 hours
Yttrium-90	To treat liver cancer	64 hours

We can evaluate the uses of radioisotopes

There are many benefits to using radioisotopes, but also some risks to consider. For example, radioisotopes in cancer treatment may destroy the primary cancer or increase the person's chances of surviving it, but they can also cause secondary tumours, due to the exposure of the body to radiation. The creation, storage, transport and disposal of radioisotopes has various risks that must be managed because radioactive material can be dangerous to health and to the environment.

Some further benefits of radioisotopes include:

- We can take measurements without having physical contact with the substance. This means that radioisotope gauges and measurement can occur in places where other methods are unsuitable, or in ways that cannot be done easily using radiation. Imagine trying to measure the thickness of aluminium foil as it moves between two rollers, and being able to do it quickly enough to adjust the rollers in real time.
- Radioisotopes require very low maintenance, and equipment is easy to maintain and use.
- The cost of manufacturing and using radioisotopes is relatively low, making it a cost-effective tool in industry and medicine.

Many of Australia's radioisotopes are made in Sydney by ANSTO, at the Lucas Heights nuclear reactor.

Figure 6.54: Scientists use radioactive tracers to locate the path of pollution from a nearby factory.

Figure 6.55: The Australian Nuclear Science and Technology Organisation at Lucas Heights, in New South Wales, is charged with conducting nuclear research and producing radioisotopes for nuclear medicine.

Learning Ladder

Reactions

1. Identify three radioisotopes and their uses, providing one example for each of industrial, medical and environment monitoring.
2. The half-life of a radioisotope can be important in relation to its use. Describe an example of where this is the case and why the half-life is important.
3. **a** Outline the type of radiation used to measure the thickness of paper.
   b Explain why this type of radiation is suitable for this use.
4. Select one radioisotope and discuss its use.
5. Select a use of radioisotopes (industrial, environmental or medical) and evaluate the societal benefits and other considerations related to this use.

Questioning and predicting

see page 401

1. A student was designing an investigation to work out which material to use for storing and transporting radioisotopes. Which of the following questions is likely to be the best to investigate? Justify your answer using your knowledge of radiation:
   A Which material provides the best protection from radiation?
   B Which materials and at what thickness does that material provide the best protection from radiation?
2. Construct a scientific question for investigating the impact of radiotherapy on the body.
3. When measuring the age of groundwater with carbon-14, a scientist was unable to get a result – no carbon-14 was detected in the sample. Propose a hypothesis to explain this observation.
4. A patient underwent a nuclear scan, and a 'cold spot' was found in a part of their brain. Predict what the cause of this cold spot could be.
5. Propose a hypothesis for an investigation to identify the most effective radioisotope for measuring the density of concrete.

In context

Investigate how radioisotopes and radioactive waste from industry and medicine are disposed of in Australia.

Success criteria

- I can outline uses of radioactive isotopes and evaluate the benefits and considerations of these uses.
- I can evaluate the benefits and considerations of using radioisotopes.

6·14 ▸ Nuclear fission and nuclear fusion

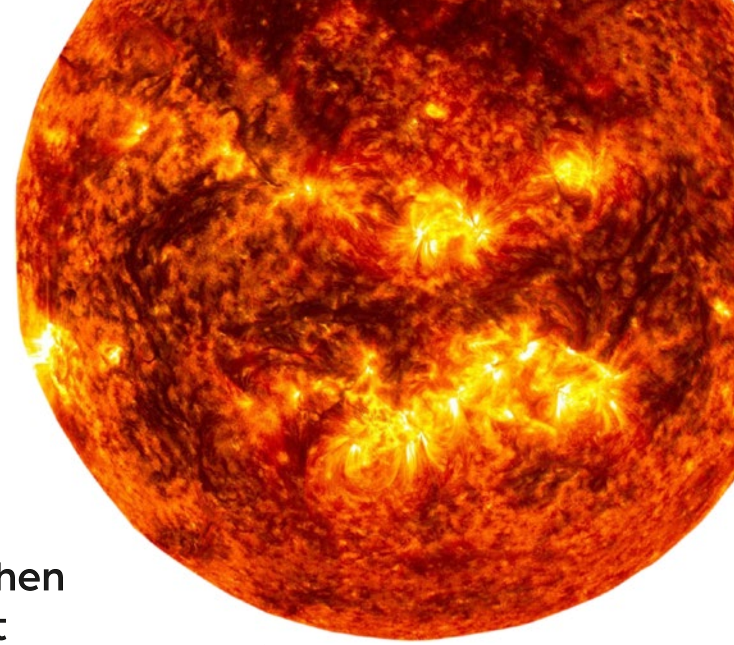


Figure 6.56: The Sun is a huge ball of nuclear fusion reactions.

Learning intention

At the end of this lesson, I will be able to describe nuclear fission and nuclear fusion.

Key terms

chain reaction: a series of reactions in which the product of one reaction is the reactant of the next reaction

control rod: a rod inside a nuclear reactor that absorbs neutrons to control the chain reaction

fission: the splitting of a heavy atom into two lighter ones

fusion: the joining of two lighter atoms to form a heavier one

Content group: Nuclear reactions

Nuclear fission and nuclear fusion are opposite types of nuclear reactions.

Fission occurs when large atoms split

Fission reactions occur when a neutron hits a larger atom, causing it to increase its energy state and split into two smaller atoms. Additional neutrons are released in fission which go on and cause more reactions in more atoms.

Fission reactions can start a **chain reaction**, where each reaction starts many more reactions and releases very large amounts of energy. An atomic bomb uses an uncontrolled chain reaction to release large amounts of energy very quickly. Figure 6.57 shows the beginning of a chain reaction, where a uranium atom is bombarded by a neutron. This splits the uranium into the lighter elements krypton and barium, which release either one or three more neutrons plus energy. These neutrons hit other uranium atoms, causing another reaction, and so on. Table 6.10 demonstrates how the numbers of neutrons increase throughout a chain reaction.

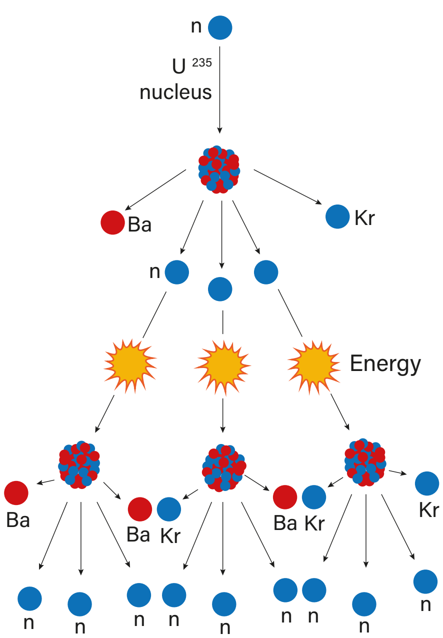


Figure 6.57: A chain reaction occurs when the neutrons released in fission cause more reactions.

Table 6.10: The number of neutrons released after each reaction cycle in a chain reaction of uranium if every reaction releases three neutrons and each causes another reaction

Reaction cycle	1	2	3	4	5	6	7	8	9	10
Number of neutrons released	3	9	27	81	243	729	2187	6561	19 683	59 049

Fission is used to generate power

Uranium and plutonium are commonly used to generate electricity, as the chain reaction can be stopped, enabling control over how much energy is produced. Table 6.10 shows that the number of neutrons released increases rapidly. Unless this is controlled, there would be an explosion, which is how fission nuclear bombs work.

In a nuclear reactor, **control rods** absorb neutrons and allow only a certain number of reactions to proceed. These rods are made of boron, silver indium or cadmium, which are dense and absorb neutrons without themselves reacting. Control rods are raised or lowered into the reaction chamber to allow more or fewer reactions and to release energy.

In a nuclear power plant, this energy is used to heat water into steam; the steam spins a turbine that generates electricity. A nuclear reactor is housed inside a shell to protect the environment and is constantly cooled by water.

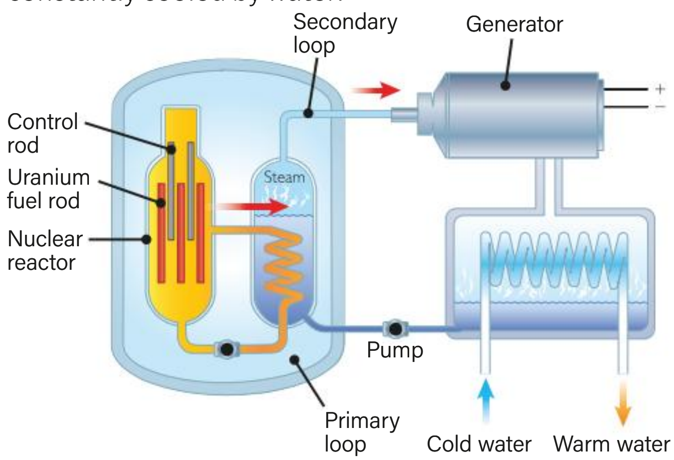


Figure 6.58: A nuclear reactor has uranium fuel rods and control rods that absorb neutrons and control the reaction.

Fusion occurs when small atoms join together

Fusion reactions occur when smaller atoms fuse or join together to form a heavier one. They create enormous amounts of energy, much more than fission reactions. They also produce new atoms of many types, as different lighter ones combine in different ways. The most common fusion reaction in the Sun is hydrogen joining to form helium, as shown in Figure 6.59. Tritium and deuterium are both isotopes of hydrogen. (They each have only one proton but different numbers of neutrons.) When they react, they produce helium and release a neutron and energy.

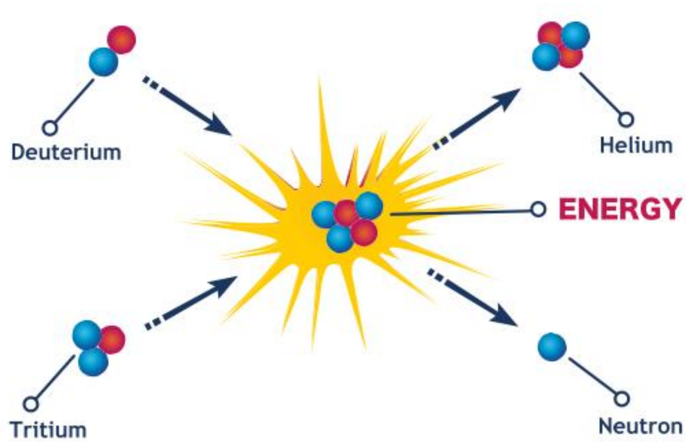


Figure 6.59: Two hydrogen atoms fuse in the Sun, producing energy, a helium atom and a neutron.

Learning Ladder

Reactions

1. Identify the main differences and similarities between a fission reaction and a fusion reaction.
2. Describe the changes that take place in a fission reaction, using an example.
3. **a** Explain how using control rods in a reactor can affect a fission reaction.
   b Construct a line graph of the data in Table 6.10.
   c Explain how the shape of the graph demonstrates a chain reaction.
4. Draw a flowchart that represents how a fission nuclear reactor generates electricity.
5. Evaluate the impact of fission and fusion on society, using examples.

Planning investigations

see page 405

Scientists want to test a variety of materials to use as control rods in a nuclear fission reactor.

1. Describe three safety precautions they could take.
2. Identify which of the following variables would be the controlled, independent and dependent variables in this investigation: type of control rod material, size of control rod, amount of uranium fuel, amount of coolant in reactor, amount of radiation produced, amount of time the experiment is run for, and the starting temperature of the reactor.
3. Construct an aim for this investigation.
4. Draft a step-by-step plan for this investigation to ensure it is valid and reliable.
5. Outline the type of data that would be collected in this investigation and assess whether you think it is appropriate based on your aim, the variables and your plan.

In context

Investigate what a tokamak is and explain what it has to do with fusion.

Success criteria

- I can describe nuclear fission and nuclear fusion reactions, using examples, and explain the differences and similarities between them.
- I can outline uses of fission and fusion and evaluate the benefits and considerations of these uses.

6.15 ▸ Environmental impacts of nuclear reactions

Learning intention

At the end of this lesson, I will be able to outline the impacts on the environment of nuclear reactions, including the raw materials used, the various stages of production and nuclear waste.

Key terms

dosimeter: a device used to measure an absorbed dose of ionising radiation

ionising radiation: radiation, made up of particles, X-rays or gamma rays, that has enough energy to cause cancer

Investigation 6.15

Nuclear energy debate, page 571

Content group: Nuclear reactions

Figure 6.60: A uranium mine in Kakadu National Park, showing the mine and tailings dam. There have been many leaks of radioactive sludge entering surrounding rocks and waterways of the national park.

Technologies that use nuclear reactions have many uses and benefits, but also risks that must be managed. The potential impacts of nuclear reactions on the environment, including from the raw material used, the processes involved and the nuclear waste produced, must be identified and assessed.

Figure 6.61: ▸ A dosimeter measures exposure to ionising radiation. Dosimeters are used by people who are exposed to radiation regularly during their work.

Nuclear energy has safety concerns

Radioactive materials release **ionising radiation** that can be useful but also dangerous. High levels of radiation, or long-term exposure to low levels of radiation, can damage living cells and lead to diseases such as leukaemia and cancer. It can also damage DNA and lead to birth defects.

There are guidelines that protect people who work with nuclear isotopes, including in medical and environmental applications and in nuclear power stations.

▲ **Figure 6.62:** These concrete shells will be used to store low-level nuclear waste that is only slightly radioactive.

Nuclear uses have impacts

Mining the raw materials for nuclear industries, such as uranium ores, has environmental impacts, including damage to land and groundwater, and the release of carbon dioxide. This is common for mining, but nuclear ore mining, especially uranium mining, produces tailings or waste rock that can release low levels of radioactive material into the environment. Some types of uranium mining use huge amounts of water that can become contaminated and if leaked will contaminate surrounding water. There are also risks with transporting the mined ore. Uranium ore is known as yellow cake. It is concentrated uranium that is radioactive and dangerous if the dust is inhaled.

After mining, most ores are processed to make them ready for use. For example, to make uranium useful, it is enriched; this process increases the concentration of the ^{235}U isotope that can be used in reactors.

In Australia, many of the medical radioisotopes used are produced by ANSTO (the Australian Nuclear Science and Technology Organisation). Production involves using a uranium-based reactor to fission uranium into other elements such as molybdenum-99, which are then used to produce other elements such as technetium-99, which have medical uses. Reactors must have a containment building made of concrete walls many metres thick to stop radiation emitted reaching the environment. Controlling radiation is easier than cleaning it up.

The radioactive materials are then packaged and transported before use. In 2024, a tiny capsule of radioactive caesium-137 used in a radioactive measurement gauge was lost on the side of the road when being transported from a mine in northern Western Australia to Perth. The capsule could have been deadly to anyone handling it. Fortunately, it was safely located, but this incident shows that there are always risks when using nuclear material.

Workers wear detectors called **dosimeters** that monitor their exposure to radiation (Figure 6.61). They may also wear special suits, or work behind thick screens, to shield them from radiation. Radioactive materials are stored and transported in secure containers.

Waste management reduces risk

The waste from nuclear technologies must be managed, treated and disposed of to avoid environmental impacts. Radioisotopes with short half-lives will become harmless after a period and are easy then to dispose of. Those with longer half-lives are more problematic. Nuclear waste can contain radioactive elements such as plutonium, which has a half-life of 24 000 years. Dangerous radioactive waste must be treated and then stored safely. Treatments and storage include encapsulating the waste in other materials that absorb radiation (e.g. bitumen, glass or concrete), and then storing it in safe and stable locations, by burying it deep underground in areas where the earth is stable.

Learning Ladder

Reactions

1. Identify an impact that may be caused by nuclear material during:
   a. mining.
   b. production of nuclear materials.
   c. disposal of nuclear materials.
2. Describe methods to protect workers from radiation while working with radioisotopes.
3. Explain, using examples, how management of nuclear waste can reduce risks.
4. Compare the methods for disposing of nuclear material with a short half-life and a long half-life.
5. Construct a list of the pros and cons of using nuclear energy.

Questioning and predicting

see page 401

1. A medical researcher was investigating the safe level of radiation exposure for workers using radioactive tracers in medical research. Select which question would be the best to investigate, and justify your answer.
   A. How long can a worker be exposed to radiation in a day without the risk of developing cancer?
   B. How much radiation can a worker be exposed to over time, to ensure the risk of cancer is minimised or eliminated?
2. There are many issues associated with managing and using nuclear material in industry.
   a. Identify one important issue related to the use of nuclear material.
   b. Construct a question to investigate an aspect of this scientific problem.
3. A scientist measuring radiation in soil found that levels were higher in the 2 km surrounding a uranium mine than in similar areas 100 km away. Propose a hypothesis to explain this observation.
4. Predict which location is the best for storing nuclear waste underground: Central Australia or New Zealand. You may need to research the geology of each country.
5. Use the information in this section to propose a hypothesis that can be investigated in regards to improving our understanding of the impact of nuclear material on the environment.

In context

Research how a Geiger counter works, and present your findings as a brochure advertising Geiger counters to nuclear industry workers.

Success criteria

- I can outline the impacts on the environment of nuclear reactions, including the raw materials used, the various stages of production, and disposal of nuclear waste.

6.16 ▶ Reactions in context

Learning intention

At the end of this lesson, I will be able to summarise a chemical process used in industry to produce an important product – sulfuric acid.

Key terms

contact process: the multistep industrial process of producing sulfuric acid

exothermic: a reaction that releases energy into the surroundings, causing the temperature to rise

oleum: an intermediate product formed between sulfur trioxide and sulfuric acid, to make the process safer ($H_2S_2O_7$)

Content group: Reactions in context

Figure 6.63: Sulfur is the starting material for the contact process to make sulfuric acid.

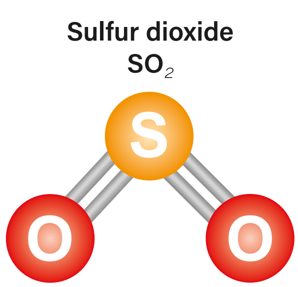


Figure 6.64: Sulfur dioxide is produced in the first step of the contact process.

Sulfuric acid is one of the most important chemicals used today. It is vital for making fertilisers, detergents and batteries, as well as in refining crude oil and manufacturing metals. The process for producing sulfuric acid involves several key steps, beginning with sulfur and ending with sulfuric acid, and shows the significance of chemistry in everyday products and industrial applications.

The contact process used in making sulfuric acid

Several steps are involved in the manufacture of sulfuric acid. Together, these steps are called the **contact process**. Each step involves chemical reactions that include features you have learnt about in this focus area.

A synthesis reaction is required to form sulfur dioxide

The first step in the contact process is a synthesis reaction in which pure sulfur is burnt in the presence of oxygen gas to produce sulfur dioxide:

$$\text{Sulfur} + \text{oxygen} \rightarrow \text{sulfur dioxide}$$

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

A catalyst is used to convert sulfur dioxide to sulfur trioxide

Sulfur dioxide is converted into sulfur trioxide (SO_3) by using a vanadium (V) oxide (V_2O_5) catalyst, which speeds up the reaction without being consumed in the process. When sulfur dioxide is heated and passed over the catalyst, it reacts with additional oxygen to form sulfur trioxide.

$$\text{Sulfur dioxide} + \text{oxygen} \xrightarrow{\text{vanadium (V) oxide}} \text{sulfur trioxide}$$

$$2SO_2(g) + O_2(g) \xrightarrow{V_2O_5} 2SO_3(g)$$

The chemical equation for this reaction shows how two molecules of sulfur dioxide react with one molecule of oxygen to produce two molecules of sulfur trioxide. Without the vanadium pentoxide catalyst, the reaction would be too slow to be an efficient industrial reaction.

Water and sulfur trioxide combine to form sulfuric acid

In the final stage of the contact process, sulfur trioxide combines with water to form sulfuric acid (H_2SO_4). This reaction is highly **exothermic**, meaning it releases a lot of heat. To make the process safer, sulfur trioxide is first absorbed in concentrated sulfuric acid to create **oleum** ($H_2S_2O_7$), an intermediate substance used which minimises the dangerous release of heat and acid mist. Water is then added to the oleum to produce sulfuric acid.

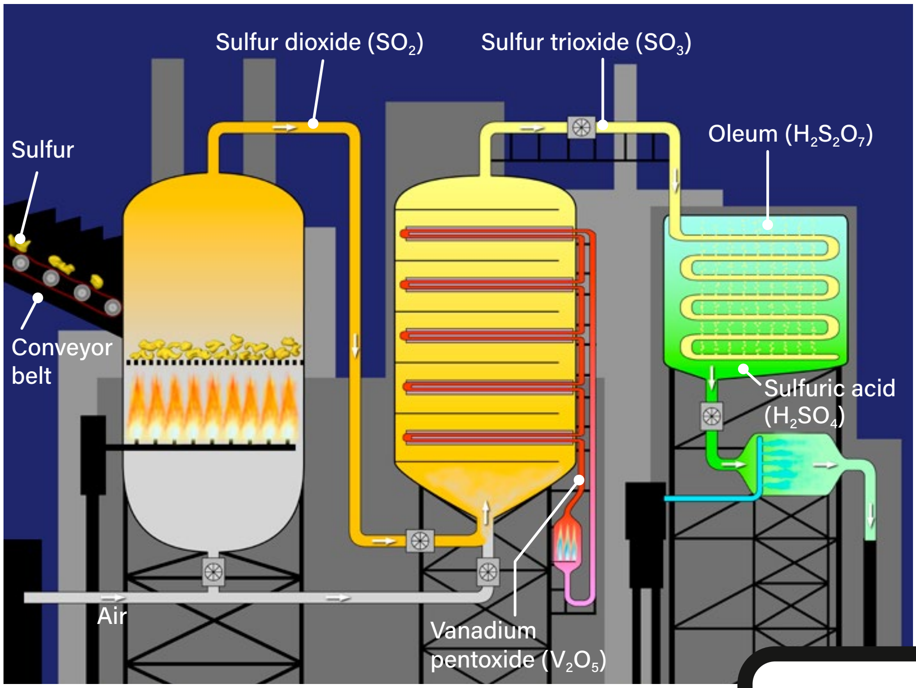


Figure 6.65: The contact process. Sulfur enters a roasting tower on a conveyor belt. Air is supplied from the bottom to produce sulfur dioxide, which is piped to the oxidising tower (centre). Catalytic oxidation (at 450 °C and under pressure) occurs in the presence of vanadium pentoxide to produce sulfur trioxide gas, which is pumped into a tank of concentrated sulfuric acid. The sulfur trioxide dissolves in the sulfuric acid to form oleum, which is diluted to form sulfuric acid.

Formation of oleum:

Sulfur trioxide + sulfuric acid → oleum

$$SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(l)$$

Dilution of oleum to form sulfuric acid:

Oleum + water → sulfuric acid

$$H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(aq)$$

Sulfuric acid is used to clean metals

A process used in metalworking to clean metals by removing rust and impurities is called pickling. It involves soaking the metal in sulfuric acid solution, which helps to clean the surface. Pickling prepares the metal for further treatments, such as painting or welding, ensuring better results and higher quality.

Figure 6.66: Metals are soaked in acid to prepare them for further industrial treatments.

Learning Ladder

Reactions

1. Identify the type of reaction used to convert sulfur dioxide into sulfur trioxide.
2. Summarise the contact process in a few sentences.
3. State and explain the factor that increases the rate of the reaction that forms sulfur trioxide.
4. Write a balanced chemical equation to represent the reaction that would take place if you were to skip the formation of oleum and, instead, go straight from sulfur trioxide to sulfuric acid by adding water directly.
5. Investigate another important product made by industrial reactions and analyse its importance to us. Select one of the following: aspirin, medical isotopes, fertiliser/ammonia, polymers, nuclear power from uranium fission.

Observing

see page 398

Refer to Figure 6.65.

1. Describe the changes that are observed throughout the contact process.
2. Construct a flowchart to reflect the observable steps involved in the contact process.
3. Based on the observed changes throughout the contact process, what inferences can be made?

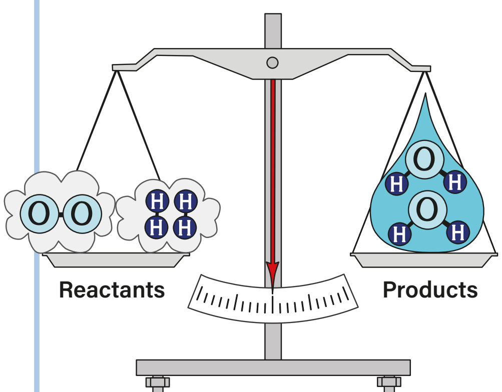
Success criteria

- I can identify the three main steps required to produce sulfuric acid.
- I can describe the types of chemical processes involved in the production of sulfuric acid

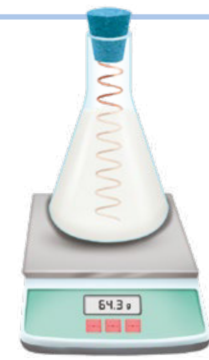
► Reactions summary

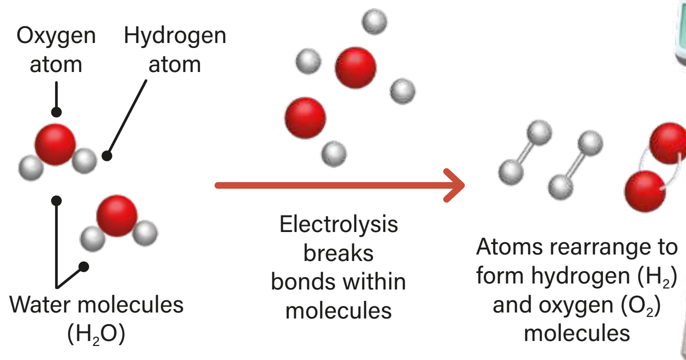
Law of conservation of mass

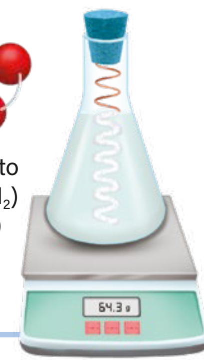
- The law of conservation of mass states that mass can never be created or destroyed.
- In a chemical reaction, mass is conserved: particles are rearranged, but the mass of the reactants is equal to the mass of the products.



- The law of conservation of mass can be observed in a closed system. In a closed system, mass cannot enter or leave, but new products are observed and mass remains constant.







Chemical reactions

- Chemical substances can be shown by their systematic (IUPAC) name or by their chemical formula.
- Rules apply for naming substances from their chemical formula.

Naming covalent compounds

H_2O

dihydrogen monoxide

Naming ionic compounds

NaCl

sodium carbonate

(cation name) (anion name)

- Chemical reactions are represented by chemical equations structured like this:

Reactants → products

For example, if you know that nitrogen (N_2) and hydrogen (H_2) react to form ammonia (NH_3), you can insert the names or chemical formulas with a reaction arrow between the reactants and the products:

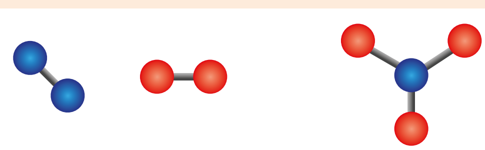
Word equation: Nitrogen + hydrogen → ammonia

Skeleton equation: $N_2 + H_2 \rightarrow NH_3$

- Chemical reactions must be balanced to reflect the law of conservation of mass.
- Steps for writing and balancing chemical equations:

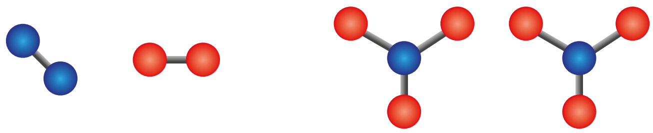
1 Write out the chemical equation for the reaction.

$N_2 + H_2 \rightarrow NH_3$



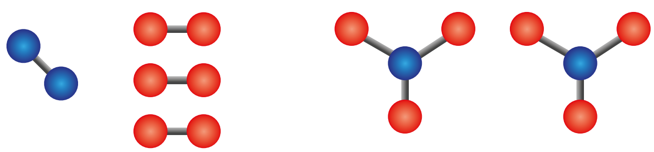
2 Balance the number of nitrogen atoms by adding a 2 in front of the NH_3 on the right-hand side:

$$N_2 \quad + \quad H_2 \quad \rightarrow \quad 2NH_3$$



3 Put a 3 in front of the H_2 on the left-hand side so there are 6 in total:

$$N_2 \quad + \quad 3H_2 \quad \rightarrow \quad 2NH_3$$

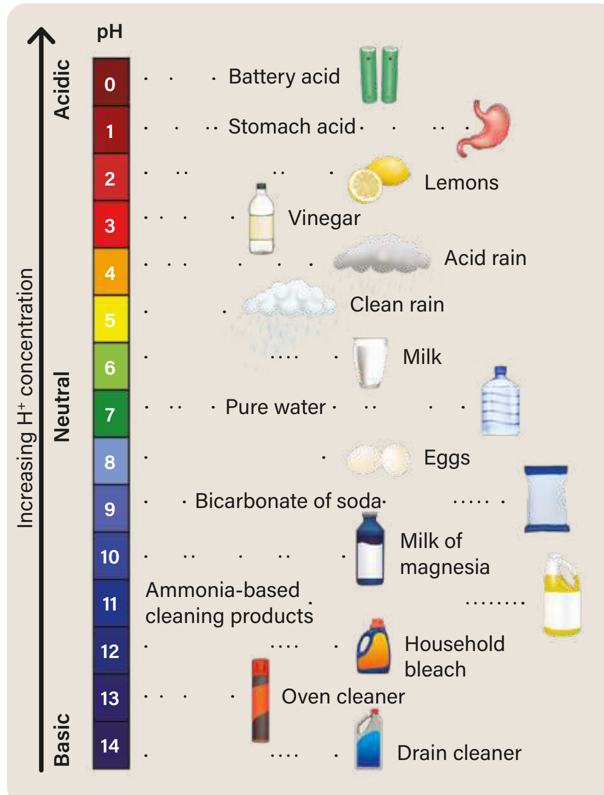


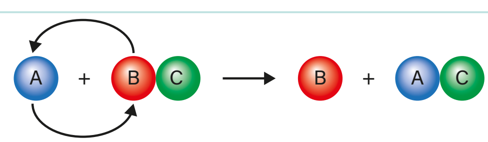
- State symbols are used after the chemical formula to show the physical state of each species:
  - **(s)** – solid
  - **(l)** – liquid
  - **(g)** – gas
  - **(aq)** – aqueous.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

- There are many types of chemical reactions, each with distinct features.

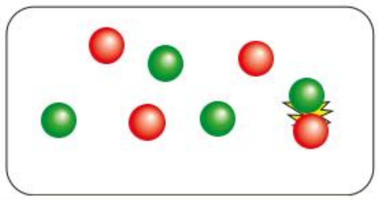
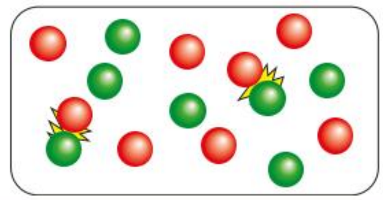
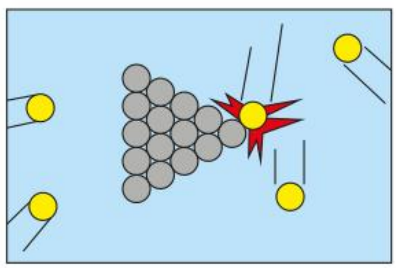
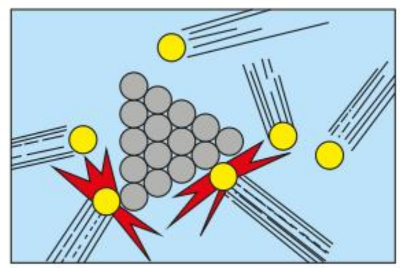
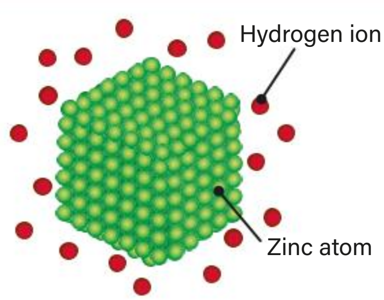
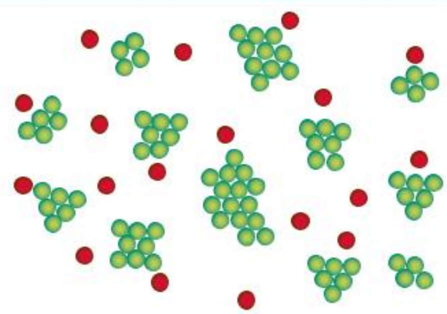
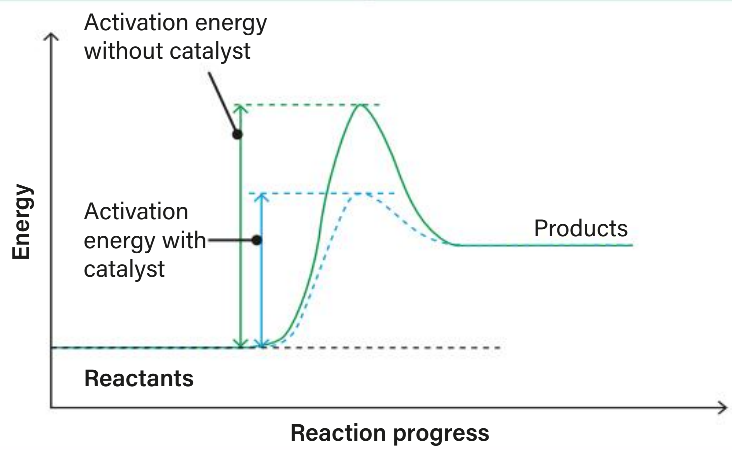
- The pH scale (0–14) measures the acidity of a substance. A pH <7 is acidic and a pH >7 is basic.
- pH indicators can be used to measure the pH change in a neutralisation reaction.



Type of reaction	Description	Examples	General equation
Combustion	A fuel reacts with oxygen to form carbon dioxide and water.	Wood burning in a campfire	Fuel + oxygen $\rightarrow$ carbon dioxide + water
Synthesis	More than one reactant combines to form a single product.	Iron rusting with oxygen to form iron oxide	A + B $\rightarrow$ AB
Decomposition	One reactant breaks down into multiple products.	Water breaking down into hydrogen and oxygen	AB $\rightarrow$ A + B
Displacement	A more reactive element replaces a less reactive one in a compound.	Copper metal replacing silver in solution to form silver metal	
Neutralisation	An acid and a base react to form a neutral salt and water.	Hydrochloric acid and marble chips reacting to form calcium chloride salt, water and carbon dioxide	Acid + base $\rightarrow$ salt + water

Rate of chemical reactions

- Collision theory helps us to predict the relative rates of reactions.
  - Sufficient energy and correct orientation of particles is required for successful collisions.
  - The higher the proportion of successful collisions in a given amount of time, the higher the rate of the reaction.
- Factors that affect reaction rate include:

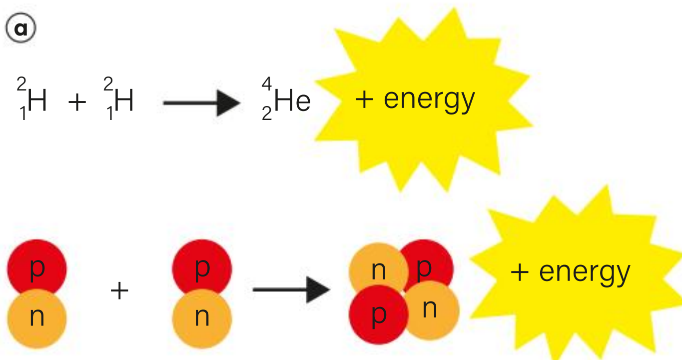
Concentration	**LOWER concentration** 	**HIGHER concentration** 
Temperature		
Surface area	 A large cube Smaller surface area Lower reaction rate	 Smaller pieces Larger surface area Higher reaction rate
Catalyst: a substance that increases the rate of a chemical reaction without being used up.		

Nuclear reactions

- Nuclear reactions involve a change in the nucleus of an atom and usually produce new elements.
- Two examples of nuclear reactions:
  - Hydrogen atoms combine to form a new helium atom.
  - Uranium is split into smaller elements.

- The big bang theory states that the universe began about 13.7 billion years ago as a small, dense region called a singularity.
- Redshift indicates that galaxies are moving away from us (i.e. the universe is expanding).
- There is an abundance of light elements. The universe is about 74 per cent hydrogen and 24 per cent helium by mass.
- Cosmic microwave background radiation, which images show as 'clumps' of matter, was released while the universe was not of uniform density.

a



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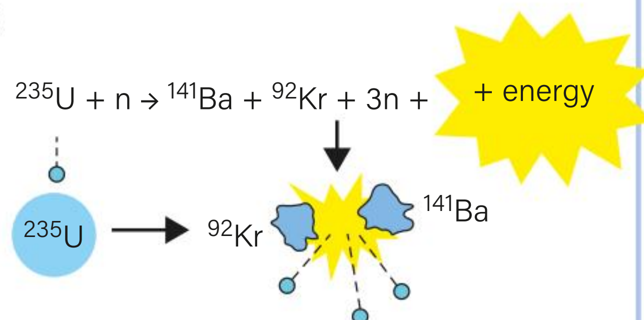
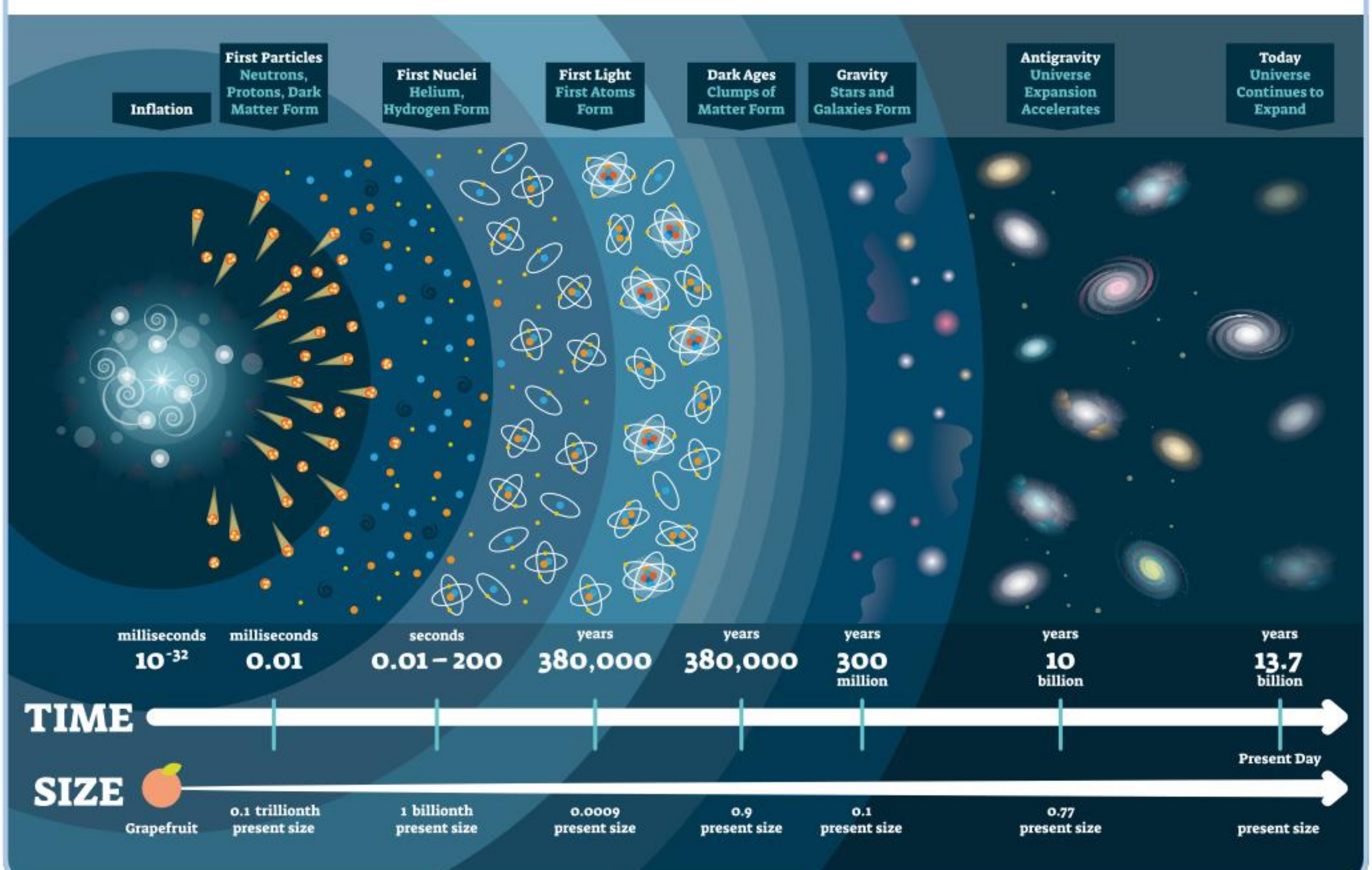
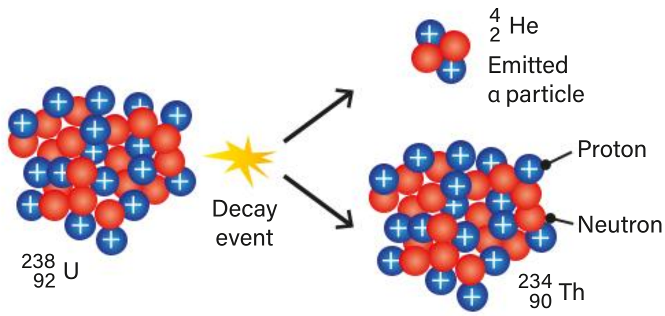
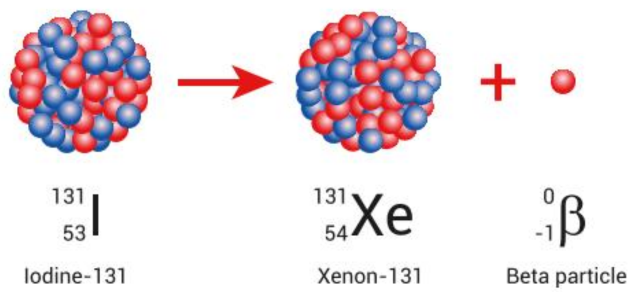




- Radioactive isotopes are unstable atoms that decay.
- When a nucleus has too many protons, it breaks down and releases energy and an alpha particle, made up of two protons and two neutrons (alpha radiation). This process forms a new element, with an atomic number two less than the original element.



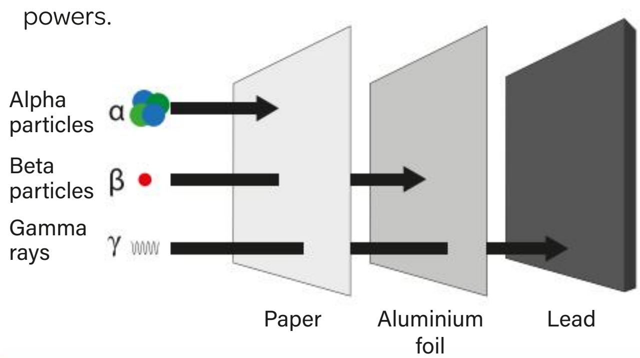
- When a nucleus has too many neutrons, a neutron breaks down into a proton and an electron. The proton is retained in the nucleus, and the electron is emitted as beta radiation.



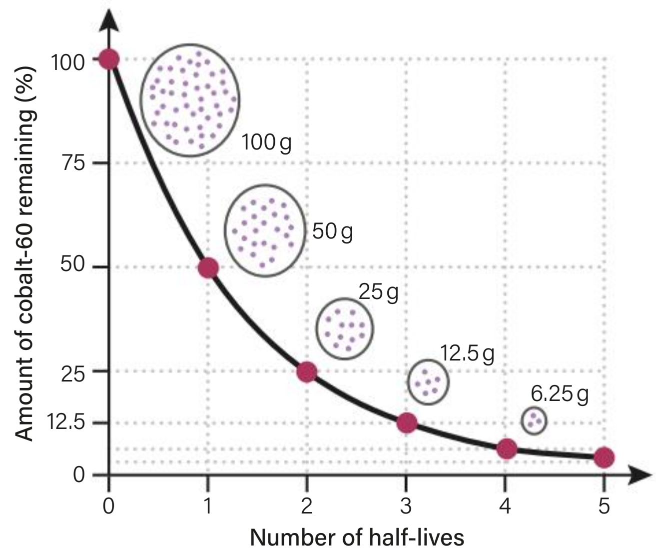
- Gamma radiation is also produced when a nucleus decays.

Particle	Symbol	Contains	Charge
Alpha	α	2 protons and 2 neutrons	+2
Beta	β	Electron	–1
Gamma	γ	High-energy electro-magnetic radiation	0

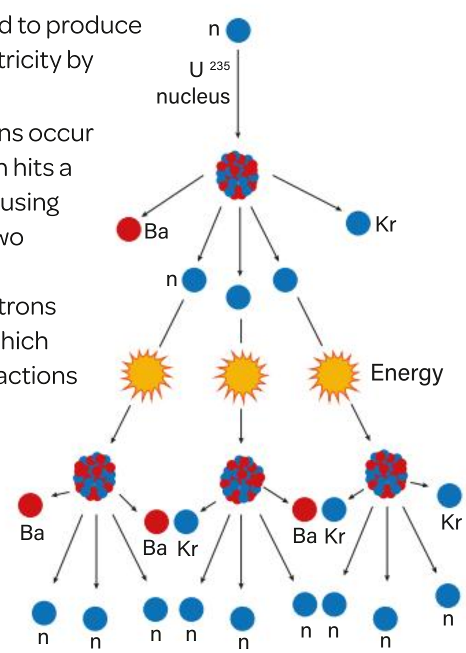
- Different radiation types have different penetrating powers.



- The half-life of a radioactive substance is the amount of time it takes for half of the radioactive isotopes in a sample to decay.

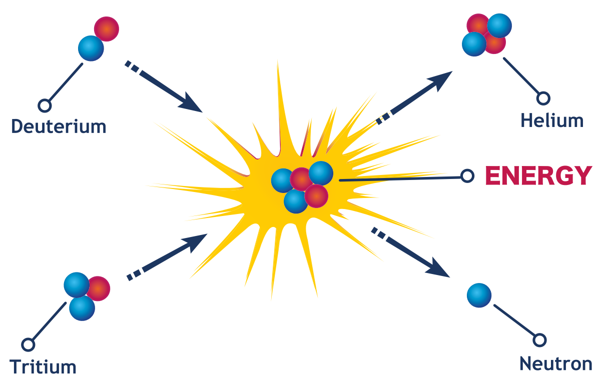


- Radioisotopes have multiple uses:
  - In radioactive dating, to work out the age of substances.
  - In industry, to sterilise food manufacturing.
  - In medicine, to diagnose medical problems and to treat cancer.
  - In environmental monitoring, to check for leaks in pipes, and to track movement of chemicals in the environment.
  - It is also used to produce energy/electricity by fission.
- Fission reactions occur when a neutron hits a larger atom, causing it to split into two smaller atoms. Additional neutrons are released, which cause more reactions and can start a chain reaction.



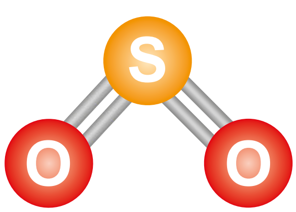
Nuclear reactions CONTINUED

- Uranium and plutonium are used to generate electricity, as the chain reaction can be managed using control rods that absorb neutrons and allow only a certain number of reactions to proceed.
- Fusion reactions occur when smaller atoms fuse or join together to form a heavier one. Fusion reactions create enormous amounts of energy and produce new atoms of many types. Fusion typically occurs in stars when two hydrogen atoms fuse, producing energy, a helium atom and a neutron.



- Radioactive materials release ionising radiation that can be useful, but also dangerous. Technologies that use nuclear reactions have many uses and benefits, but also risks.
  - There are guidelines that protect people who work with nuclear isotopes.
  - Workers wear dosimeters that monitor their exposure.
  - Mining the raw materials for nuclear industries, such as uranium ores, can damage the land and groundwater.
  - Reactors must have a containment building to stop radiation reaching the environment.
  - Transporting nuclear materials requires special processes.
  - Radioisotopes with short half-lives will become harmless after a period and are then easy to dispose of.
  - Those with longer half-lives require long-term storage solutions and ongoing management.

Reactions in context



Sulfur dioxide
SO_2

- The contact process uses many chemical reactions and processes to produce sulfuric acid, a crucial product used in industry. Examples include:
  - the synthesis of sulfur dioxide:

$$\text{Sulfur} + \text{oxygen} \rightarrow \text{sulfur dioxide}$$
$$S(s) + O_2(g) \rightarrow SO_2(g)$$

  - the use of a catalyst to form sulfur trioxide:

$$\text{Sulfur dioxide} + \text{oxygen} \xrightarrow{\text{vanadium (V) oxide}} \text{sulfur trioxide}$$
$$2SO_2(g) + O_2(g) \xrightarrow{V_2O_5} 2SO_3(g)$$

- Sulfuric acid is vital for making fertilisers, detergents and batteries, as well as in refining crude oil and manufacturing metals.

Masterclass

Steps in progression

		1	2
Content	**Reactions**	Identify a reaction as endothermic or exothermic if the surrounding temperature changes from 25°C to 20°C.	Describe at least two things you might observe when an exothermic reaction takes place.
Processes	**Observing**	Identify a tool that could be used to determine if a reaction is endothermic or exothermic.	Describe how the tool identified in step 1 would be used and provide examples of measurements that would be recorded.
Processes	**Questioning and predicting**	Which of these scientific questions is most appropriate? **A** Which instant heat pack brand is the best? **B** How do different brands of instant heat packs differ in the maximum temperature reached?	Construct a scientific question to investigate how to make the most effective ice pack using ammonium nitrate.
Processes	**Planning investigations**	Describe three ways that you would reduce risk when investigating the effectiveness of a $CaCl_2$ heat pack.	Classify the following variables as controlled, independent or dependent: temperature of a system, surface area $CaCl_2$, mass of $CaCl_2$.
Processes	**Conducting investigations**	Look up the Safety Data Sheet for calcium chloride and ammonium nitrate and outline their safety and environmental considerations.	Sketch and label an apparatus that could be used to test the efficiency of a variety of heat pack brands.

The energy of reactions

Hot and cold packs are great examples of how 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 dissolved in water, it releases energy in an exothermic reaction observed as heat, which increases the temperature of the area surrounding the chemical reaction.

$$CaCl_2\,(s) \xrightarrow{H_2O} Ca^{2+}(aq) + 2Cl^{-}(aq) + \text{heat}$$

Figure 6.67: Exothermic reactions can be contained in a package to be marketed as instant heat packs for hand and feet warming.

Demonstrate your understanding

3	4	5	
Explain why crushed $CaCl_2$ in a heat pack would feel warmer than the same amount of a solid cube of calcium chloride ($CaCl_2$).	Write a balanced chemical equation to represent the reaction that takes place in a typical instant cold pack, including state symbols.	Discuss the environmental implications of using disposable instant ice packs and suggest ways to minimise their impact.	
Make an inference based on a bright light that is observed during a chemical reaction.	Are the chemicals in instant cold packs toxic? Describe observations that could help you to address this question.	Evaluate the following statement: 'A digital thermometer will be better at classifying endothermic and exothermic reactions than an analog one.'	Science how-to p. 398
Propose a hypothesis for the scientific question constructed in step 2.	Assess your hypothesis against the required conventions and make adjustments to include relevant variables and controls as necessary.	Evaluate the scientific questions in step 2 alongside the hypothesis in step 4, making reference to scientific theory.	Science how-to p. 401
Develop an aim for an investigation that incorporates the variables classified in step 2.	Produce a step-by-step method to address the investigation aim proposed in step 3 that is ethical, reliable and valid.	Describe the type of data that would be generated in your investigation and evaluate its appropriateness in addressing the aim.	Science how-to p. 405
Identify and explain two different errors apparent in the apparatus from step 2 that could impact the quality of collected data.	Discuss how data, information, evidence and findings could be accurately collected and recorded by using the apparatus sketched in step 2.	Conduct an online search to locate numerical data related to instant heat or cold packs and construct an appropriate reference to the source.	Science how-to p. 408

In an exothermic reaction, energy is released into the surroundings, causing the temperature of the pack to rise and making it feel warm. This reaction is often used in reusable hand warmers and in some therapeutic packs for sore muscles.

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 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 and making it feel cold.

These reactions are useful in everyday products for providing quick heat or cold, and help to illustrate how chemical reactions can change energy to produce practical effects.

Figure 6.68: 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.

Focus area 7

7.0 Waves and motion

Surfing is a popular sport in Australia. Surfers can ride a wave because of the energy in the wave. Waves are moving energy, and this energy can be used to lift and push a surfer up onto the face of the wave. As the surfer then continually falls down the face of the wave, gravitational potential energy is converted to kinetic energy – the energy of movement or motion. In this focus area, we will learn about waves and motion, and how we use them in our daily life – both for fun and in the important technologies we have developed.

▲ **Figure 7.1:** Sound is a wave that travels faster under water than in air.

Learning Ladder

The Learning Ladder contains the scientific content and processes you will learn in this focus area . Each area has five levels of progression. To move to higher levels, you need to practise activities at the earlier levels. This will help you develop the ability to complete tasks that are more complex.

Steps in progression	Content: Waves and motion	Working scientifically processes: Conducting investigations	Working scientifically processes: Processing data and information	Steps in progression
5	I can analyse our understanding of waves and motion and their impacts on society.	I can extract data from secondary sources and construct appropriate references to acknowledge their use.	I can evaluate investigations based on the quality of processed data.	5
4	I can quantify and compare the features of waves, and analyse and calculate mathematically an object's motion.	I can accurately collect and record data, information, evidence and findings from first-hand and second-hand investigations.	I can use data to support or refute questions, hypotheses or solutions to problems.	4
3	I can explain the applications of waves and the motion of objects.	I can conduct first-hand investigations and accurately record the collected data and identify errors.	I can process and interpret quantitative and qualitative data from a range of sources.	3
2	I can describe and compare the properties of waves and of objects in motion.	I can use scientific equipment to conduct investigations and gather first-hand data and information.	I can organise and represent data in appropriate ways, including in tables and graphs.	2
1	I can identify features of waves and of objects in motion.	I can implement safe practices when using scientific equipment.	I can select and extract information from various texts and sources.	1

Figure 7.2: Surfing uses the energy of the wave to create motion.

7·1 ▸ Wave types

Learning intention

At the end of this lesson, I will be able to explain what a wave is and the difference between basic types of waves and how they transfer energy.

Key terms

compression: an area in a wave where particles are close together

longitudinal wave: a mechanical wave in which the particles of the medium vibrate in the direction the wave is moving

matter: a substance made of particles

mechanical wave: a wave that moves energy through matter by vibrating particles

medium: a substance through which a wave can travel

rarefaction: an area in a wave where particles are spaced out

transverse wave: a wave that vibrates at right angles to its direction of motion

vacuum: empty space

wave: moving energy

Investigation 7.1

Making a wave machine, page 573

Content group: Common properties of waves

▲ **Figure 7.3:** Ocean waves are transverse waves.

Sound, visible light, microwaves, water waves or surf at the beach, and even earthquakes, are all waves.

Waves transfer energy, not matter

A **wave** is the transfer of energy from one place to another. **Mechanical waves** (e.g. sound) require **matter** (or a **medium**) to move through. When mechanical waves travel through matter, the particles of the matter carry the energy for a short period of time. The particles may vibrate or move as they transfer energy but, after the energy passes through, they return to their starting position. This means only the energy is transferred, but the matter is not – the matter stays in place.

Not all waves need a medium to travel through

Sound cannot travel through a **vacuum** such as outer space, because there is no matter or particles for it to pass through. However, light waves (a type of electromagnetic wave) do not need a medium to travel through. This is why light waves and other types of electromagnetic waves such as infrared waves can travel from the Sun, through empty space, to Earth.

Longitudinal waves vibrate in the same direction as their movement

A **longitudinal wave** is a mechanical wave in which the particles of the medium vibrate in the direction that the wave is moving – they vibrate in the same direction as the energy transfer. You can push and pull the ends of a slinky to make a longitudinal wave. Sound waves and some earthquake waves are longitudinal waves.

A longitudinal wave has different regions called **compressions** (where the particles are close together) and **rarefactions** (where the particles are spaced apart) (Figure 7.4).

The wavelength of a longitudinal wave is the distance between two compressions and is measured in metres (m) or centimetres (cm).

The denser the material, the faster the sound travels. This is why sound travels faster through liquids (e.g. water) or solids (e.g. glass) than through air.

Transverse waves vibrate at right angles to their movement

Transverse waves vibrate at right angles to their direction of motion – they vibrate 'up and down', rather than 'back and forth'. You can produce a transverse wave by moving the ends of a skipping rope up and down. The more effort is used in moving the rope, the bigger the waves, and moving the rope up and down faster creates more waves. The vibrating strings in musical instruments, ocean waves and light waves are all types of transverse waves.

Transverse waves such as ocean waves are mechanical and require a medium to travel through. Transverse waves such as light (electromagnetic waves) do not require a medium to move through.

The wavelength of a transverse wave is the distance between two wave peaks (or two troughs) (Figure 7.4).

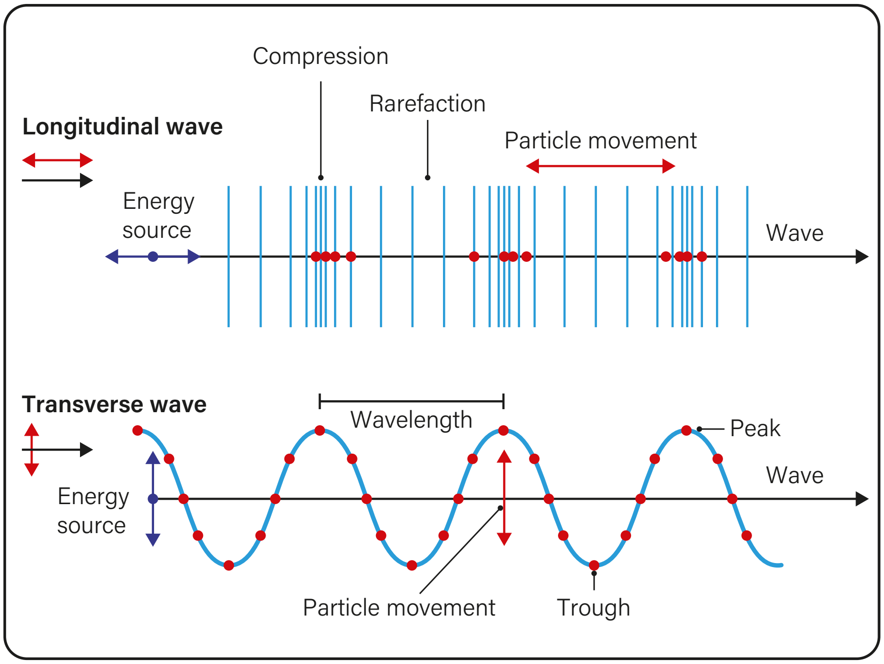


Figure 7.4: Comparing particle and energy movement in waves

When transverse waves travel through a medium, the particles of the medium vibrate perpendicularly (at right angles) to the direction the wave is moving; that is, they vibrate at right angles to the direction of energy transfer.

Learning Ladder

Waves and motion

1. Draw and label a:
   - **a** longitudinal wave.
   - **b** transverse wave.
2. Describe and compare the properties of longitudinal and transverse waves.
3. Provide an example of how we use a longitudinal wave and a transverse wave.
4. Imagine you and a friend are holding the ends of a rope.
   - **a** How would you move your hand to make a transverse wave?
   - **b** How would you make more waves?
   - **c** How would you make larger waves?
5. Think of one way that the use of a wave has affected our society. Explain why this is important.

Conducting investigations

see page 408

Imagine you are using a slinky to observe and measure the properties of longitudinal and transverse waves.

1. Suggest some safety measures you may need to consider.
2. List the equipment you would need to measure wavelength and speed.
3. Construct a table to record your observations and measurements for speed and wavelength.
4. Identify the units you will use for measuring the wavelength and speed. You may need to look up the unit for speed and how to calculate it.
5. Research and record the speed of five types of waves: sound, light, radio, and two waves of your choice. Include a reference for your sources of data. (See the Science how-to section on page 443.)

In context

Investigate one use of sound waves and produce a short presentation in a format of your choice to demonstrate this use and its the importance to society. Acknowledge your source with appropriate references.

Success criteria

- I can explain what a wave is and how energy is transferred in waves without the transfer of particles.
- I can use models to compare and describe the features of transverse and longitudinal waves.
- I can demonstrate that a mechanical wave requires a medium to travel through, whereas an electromagnetic wave does not.

7.2 ► Features of waves

Figure 7.5: The largest waves in the world occur at Nazare, Portugal. Amazingly, some surfers manage to ride them! This wave can be seen crashing into cliffs and a lighthouse after a major Atlantic Ocean storm.

Learning intention

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

- describe the features of waves in a range of wave types
- explain mathematically the relationship between a wave's frequency, speed and wavelength.

Key terms

amplitude: the height of a wave measured from its midpoint

frequency: the number of waves that pass a point every second

tsunami: a large sea wave caused by an earthquake

wavelength: the distance from the peak of one wave to the peak of the next wave

Investigation 7.2

Waves in a slinky and calculating frequency, page 575

Content group: Common properties of waves

All waves have similar features, and these allow us to study the properties of waves and to compare them. Amplitude, speed and frequency can be measured and are related. Our understanding of waves allows us to find uses for them. Maybe, if we can understand waves better, we can work out how to stop waves like tsunamis causing damage.

We can measure wave features

Both transverse and longitudinal waves have three properties:

- **Frequency** is the number of waves that pass a point every second. Frequency is measured in hertz (Hz). High-frequency waves carry more energy than low-frequency waves. In a sound wave, a higher frequency causes a higher pitch (Figure 7.6).
- **Wavelength** is the distance from the peak of one wave to the peak of the next wave. It is measured in metres (m), centimetres (cm) or similar units. A wave with a shorter wavelength carries more energy than one with a longer wavelength. Wavelength is expressed by the symbol λ (the Greek letter lambda).

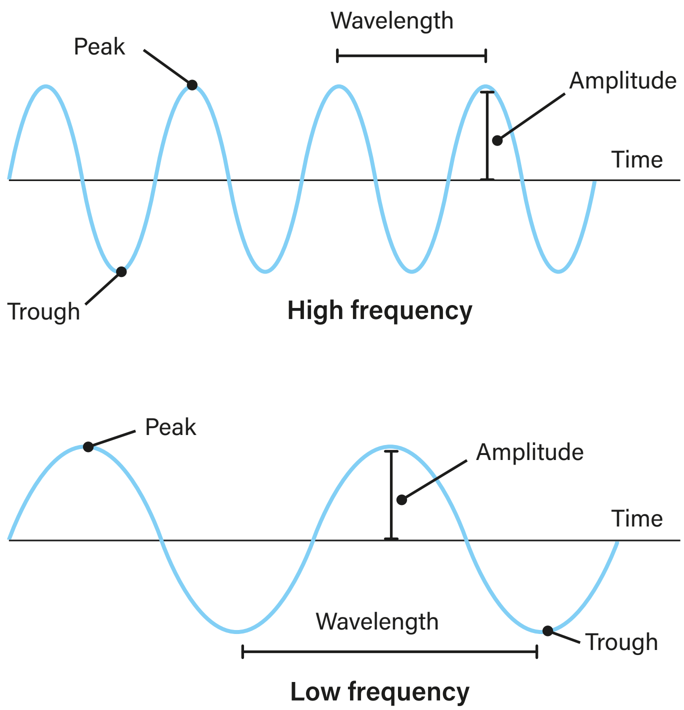


Figure 7.6: Waves can have a higher or lower frequency and a long or short wavelength.

- **Amplitude** is the distance from the peak (top) or trough (bottom) of a wave to the middle of its position. A wave with a high amplitude has more energy than a wave with a low amplitude (Figure 7.7). In a sound wave, a high amplitude results in a louder sound.

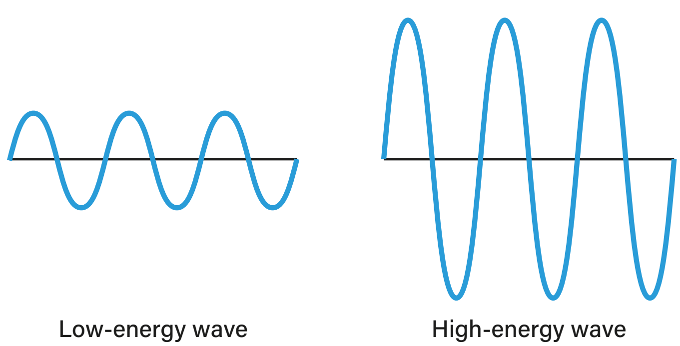


Figure 7.7: A wave with a high amplitude carries more energy than a wave with a low amplitude.

We can observe the relationship between frequency and wavelength

When observing waves, we know that:

- as the wavelength gets longer, the frequency must decrease, because there will be fewer waves per second
- as the frequency increases, the wavelength must get shorter.

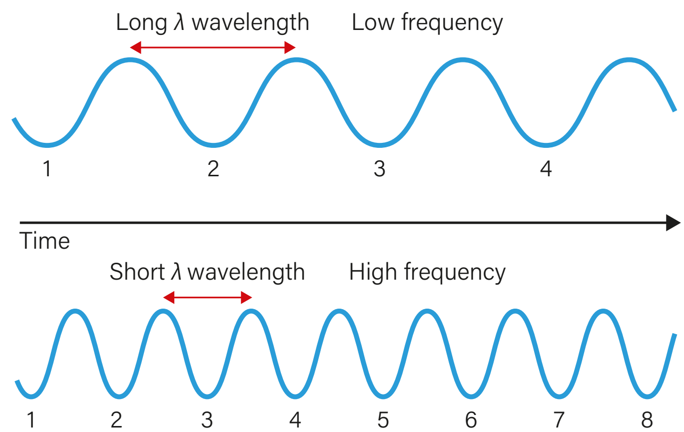


Figure 7.8: A longer wavelength means a lower frequency.

We can calculate the relationship between wavelength, speed and frequency

The formula for the relationship between a wave's frequency, speed and wavelength is:

$$\lambda = \frac{v}{f}$$

where:

λ = wavelength (m)

v = speed, sometimes called velocity, in metres per second (m s^{-1})

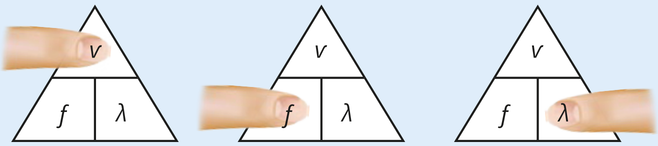
f = frequency in hertz (Hz).

The equation $v = f\lambda$ tells us that the speed of a wave is directly proportional to both its frequency and its wavelength. For example, if frequency increases, and speed remains constant, the wavelength must decrease. Similarly, if wavelength increases and speed remains constant, the frequency must decrease.
We can calculate this relationship using the formulas in Figure 7.9.

To find speed:

To find frequency:

To find wavelength:



$v = f \times \lambda$

$f = \frac{v}{\lambda}$

$\lambda = \frac{v}{f}$

Figure 7.9: Calculations are easy using the $v = f\lambda$ triangle. Cover the value you need to know and use the other two values to complete the calculation.

For example: If frequency is 100 Hz and wavelength is 2 m, then we can calculate the speed:

$$v = f\lambda$$
$$= 100 \times 2$$
$$= 200 \text{ m s}^{-1}$$

Or, if speed is 10 m s^{-1} and frequency is 2.5 Hz, then we can calculate the wavelength:

$$\lambda = \frac{v}{f}$$
$$= \frac{10}{2.5}$$
$$= 4 \text{ m}$$

Tsunamis demonstrate the relationship between wavelength, speed, frequency and amplitude

Tsunamis are giant waves that are often caused by earthquakes pushing large amounts of water upwards. In the deep ocean, tsunamis have huge amounts of energy but a small amplitude – that is, the wave does not appear very large. In the deep ocean, they also have a long wavelength and low frequency.

As the tsunami approaches shallow water around land, the wave slows. Reducing the speed does not change the frequency, so, according to the equation, it must have a shorter wavelength than before. Having a shorter wavelength causes the wave to increase in height in shallow water – that is, the amplitude increases. We know that a wave with higher amplitude has more energy than a wave with lower amplitude. In a way, the wave gets 'squashed' as it slows and forces the water upwards, making a wave that can be over 30 metres high and still carrying a lot of energy.

In the deep ocean, the energy is carried as kinetic energy as the wave moves. But when the wave grows higher, its kinetic energy is transformed into gravitational potential energy – the water is forced upwards and has stored energy due to gravity. When it reaches land, this energy causes the water to flow over and damage everything in its path as it loses energy.

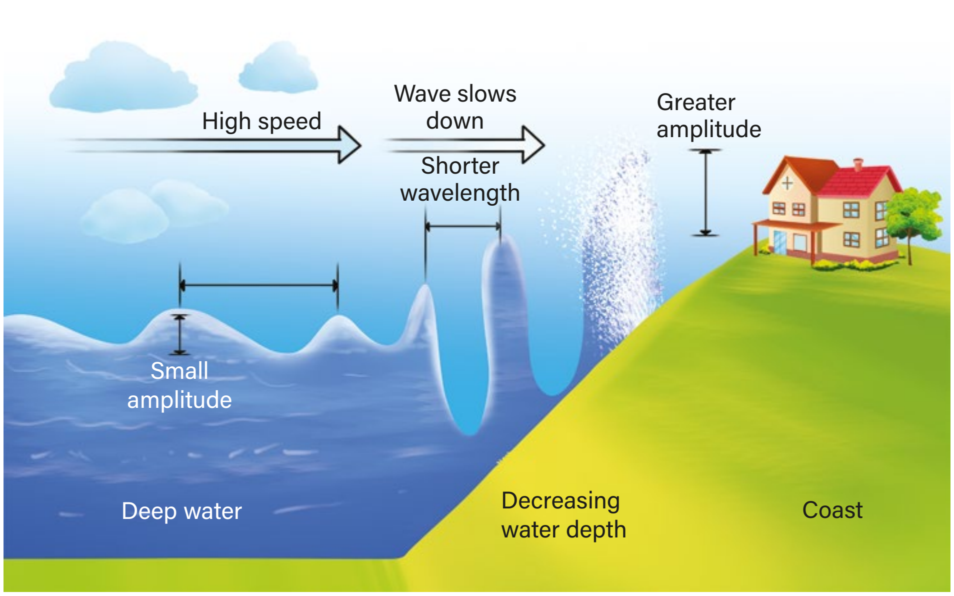


Figure 7.10: When a tsunami approaches shallow water, it demonstrates the relationship between wavelength, speed, frequency and amplitude.

Figure 7.11: A tsunami can cause massive damage due to the high amount of energy carried in the wave.

Learning Ladder

Waves and motion

1. Draw a transverse wave and label the wavelength, amplitude, direction of energy transfer, crest and trough.
2. Compare and contrast:
   a amplitude and speed.
   b wavelength and frequency.
3. Using what you know about waves, explain how waves can be used for surfing.
4. Use the formula $v = f\lambda$ to copy and complete the following table.

Speed (v) ($m\,s^{-1}$)	Frequency (f) (Hz)	Wavelength (λ) (m)
2		10
	50	6
340	0.8	
	2546	0.13
25		0.5
341	824	

5. A scientist measured the amplitude and wavelength of ocean waves and calculated the amount of energy in each wave. Look at the following two pairs of waves.

Wavelength (m)	Amplitude (m)	Energy (J)
16	0.5	200
8	1.0	200
20	1.5	600
10	3.0	600

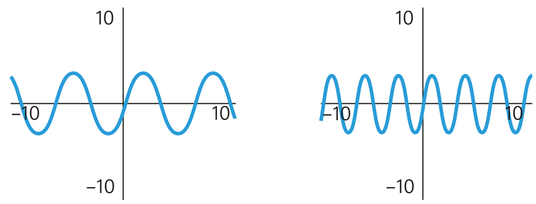
   a Describe what happened to the amplitude when the wavelength decreased.
   b Describe what happened to the energy in the wave when the wavelength reduced and amplitude increased. Explain how this relates to a tsunami.

Conducting investigations

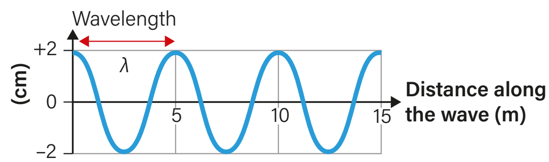
see page 408

1. Construct a risk assessment for an investigation using a rope to create transverse waves.
2. If conducting an investigation into transverse waves using a rope, identify the equipment and units you would use to measure:
   a amplitude.
   b frequency.
   c wavelength.

3. A student conducted an investigation into waves and concluded the following: In a transverse wave, the particles move in the same direction as the wave energy. The amplitude of the wave is measured in Hz and gets smaller when more energy is put into the wave.
   Copy and correct this conclusion.
4. A student conducted an investigation and collected information to construct the following two graphs. Explain the difference between the two waves.



5. Consider the following the wave.



   a What is the wavelength?
   b How many complete waves are shown?
   c What is the amplitude?
   d What is the total height of the wave, and how does this relate to the amplitude?

In context

When you throw a rock into a pond, it sends ripples (waves) across the water. Predict why the ripples get smaller, the further from the rock they travel. Suggest what happens to the energy carried by the waves. Propose how you could make larger waves.

Success criteria

- I can describe amplitude, frequency, speed and wavelength for a range of wave types.
- I can use the formula $v = f\lambda$ to explain and calculate the relationship between a wave's speed, frequency and wavelength.

7.3 ▸ The electromagnetic spectrum

Learning intention

At the end of this lesson, I will be able to compare the different waves of the electromagnetic spectrum, including their uses and properties.

Key terms

electromagnetic spectrum: all the different electromagnetic waves

UV: ultraviolet

Content group: Common properties of waves

We use electromagnetic waves every day – to heat up food, in mobile phones, in TV remote controls and to listen to the radio, in medicine and to see objects.

Electromagnetic radiation travels in waves

Electromagnetic waves originate from the Sun and other stars, and travel through the vacuum of space in different forms. They make up the **electromagnetic spectrum** and are transverse waves made up of magnetic fields and electric fields travelling together. All electromagnetic waves travel at 300 000 km s^{-1} – the speed of light – and have different wavelengths and frequencies (Figure 7.12). As wavelength decreases, frequency and energy increase.

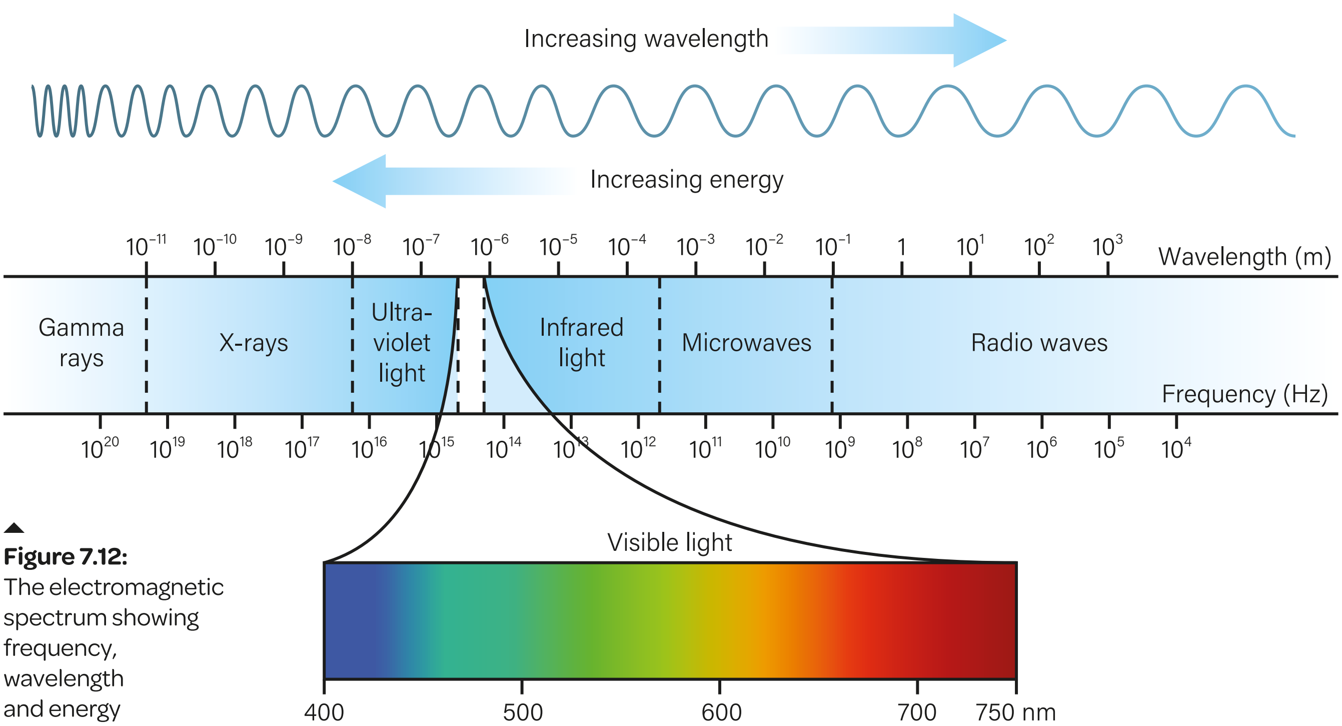


Figure 7.12: The electromagnetic spectrum showing frequency, wavelength and energy

Some electromagnetic waves have high energy

Gamma rays, X-rays and UV waves are high-energy waves. Gamma rays can pass through and damage cells in your body. They can penetrate lead and concrete, and are used in industry for detecting cracks in metal structures. They are also used for sterilising medical equipment, for the treatment of cancer and in CT scans.

X-rays are produced when high-energy electrons hit a metal surface. Denser materials absorb more X-rays than less dense materials. X-rays can produce images of bones because they are absorbed by bones but pass straight through soft tissue. X-rays are also used to kill cancer cells and to scan baggage.

Ultraviolet (**UV**) rays have shorter wavelengths and higher frequencies than violet rays. UV light is used in forensic science to detect blood or other substances, and to check signatures for forgeries.

Figure 7.13: A forensics officer collecting evidence. Having dusted a glass with powder, the officer is using an ultraviolet (black light) torch to reveal fingerprints.

Some electromagnetic waves have low energy

Visible light, infrared light, radio waves and microwaves are low-energy waves. Visible light is the only part of the spectrum that we can see. Our eyes contain special cells that detect visible light.

Infrared light has a lower frequency and longer wavelength than red light. Infrared light is used in electric heaters, short-range communications (i.e. remote controls) and thermal imaging cameras, which can detect heat.

Microwaves have shorter wavelengths than radio waves. Lower-energy microwaves are used in home wi-fi and mobile phone communications. Shorter, higher-energy microwaves are used to cook food.

Radio waves have the longest wavelength and lowest energy and are used for broadcasting television and radio, and in communications and satellite transmissions.

Learning Ladder

Waves and motion

1. Identify one property of, and one use for, each of the seven types of electromagnetic waves (see Figure 7.12).
2. Compare and contrast the properties of infrared and visible light.
3. Explain why X-rays can be used to scan inside the body.
4. Explain the relationship between wavelength, frequency and energy, and use this information to compare the uses of gamma rays and radio waves.
5. Provide two examples of how our understanding of electromagnetic waves has affected society.

Processing data and information

see page 412

1. Draw a line and label one end 'low energy' and the other end 'high energy'. Using the information in this section, write the following uses of electromagnetic waves on your line in the correct order: microwave oven, CT scanner, X-ray machine, mobile phone, television, heat lamp, a black light, bedside lamp.
2. Create a simple table to compare electromagnetic waves. Order the waves from highest to lowest energy. Include the name of the wave, wavelength, frequency and one other piece of information of your choice.
3. Construct a table showing each type of electromagnetic wave and the wavelength with units. Conduct research to identify an object that can help demonstrate the size of each wave.
4. Jin says that when her mother turns on the microwave oven, it interferes with the home wi-fi. Support or refute Jin's statement using your knowledge of electromagnetic waves.
5. The device that measures an electromagnetic wave must be similar in size to the wavelength. What size detector may improve the ability to collect radio waves? Find out what device is used to detect radio waves from space. How large may it be?

In context

Home wi-fi uses microwaves to communicate between the router/modem and your devices. Find out the frequencies (or bands) used for your home wi-fi and compare each band.

Success criteria

- I can compare the different wave forms of the electromagnetic spectrum.
- I can use data to compare the uses of different electromagnetic waves based on their properties.

7.4 ▶ Sound energy

Learning intention

At the end of this lesson, I will be able to model how sounds waves travel and describe their properties.

Key terms

pitch: the frequency of sound, measured in hertz (Hz)

sound: a mechanical wave that transfers energy through vibrating particles

volume: the loudness or amplitude of sound, measured in decibels (dB)

Investigation 7.4

Investigating amplitude, frequency and pitch of sound waves, page 576

Content group: Sound waves

Sound is one of our main communication methods. We enjoy music, and we use sonar to detect objects underwater and ultrasound to look inside the body. **Sound** is a mechanical, longitudinal wave that requires a medium to travel through. When sound travels, the particles vibrate and then return to their starting position.

Sound waves are made up of rarefactions and compressions

In a speaker, the cone moves back and forth to create vibrations. When it moves forward, the cone pushes the air particles closer together and the air pressure increases as a compression forms. When the cone moves backwards, it creates a rarefaction. The energy is passed from one particle to the next as the wave moves through the air.

The rarefactions and compressions in a longitudinal sound wave can be represented on a graph in a transverse wave form (Figure 7.14).

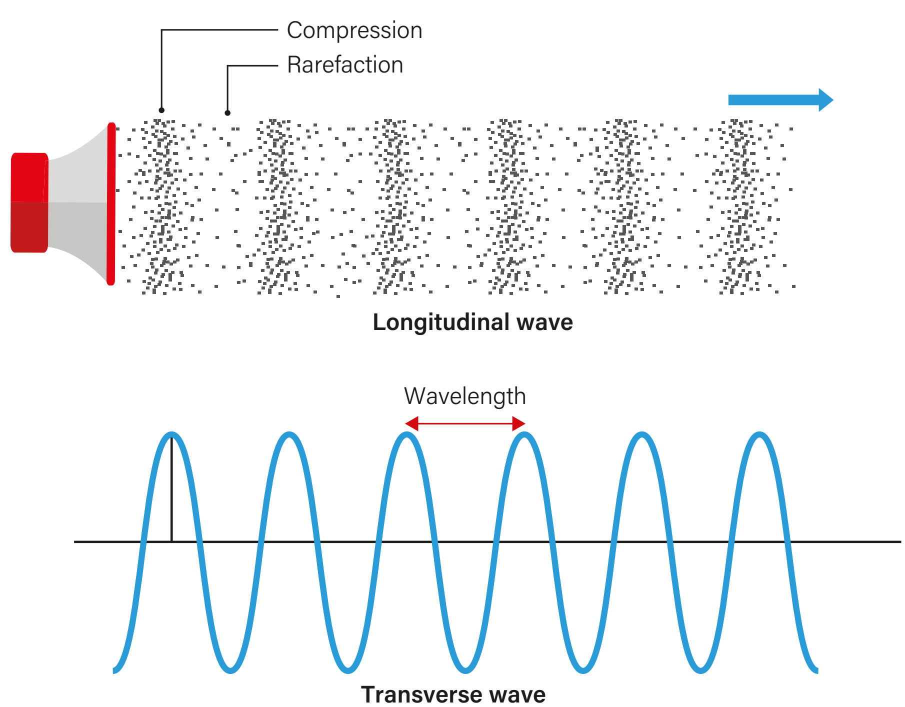


Figure 7.14: ▶ Compressions and rarefactions on a longitudinal sound wave can be represented as a transverse wave form.

Frequency is related to pitch

The **pitch** of a sound is known as its frequency and is measured in hertz (Hz). A high-pitch (high-frequency) sound occurs when the pressure waves (or compressions) are close together and the wavelength is short. When the waves are further apart, the wavelength is longer and the sound has a lower pitch (low frequency) (Figure 7.15).

Amplitude is related to volume

The **volume** or loudness of a sound is related to how much energy the wave is carrying. Volume is measured in decibels (dB). If you hit a drum softly with a small amount of energy, it creates a quiet sound. Hitting the drum harder with more energy creates a louder sound. The volume is shown as the amplitude, or the size of the wave. The higher the amplitude, the louder the sound.

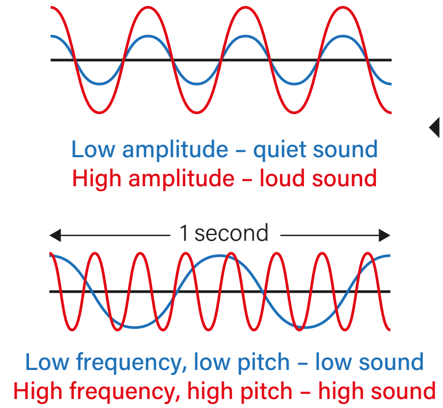


Figure 7.15: The amplitude of a sound is related to its volume, and its pitch is related to its frequency.

Sound can travel at different speeds

Sound travels faster through denser solids, such as metals, than through less dense solids, such as rubber. This is because the particles in metals are closer together and pass on their energy to each other very quickly.

Particles in liquids are more spread out than particles in a solid, so sound waves move more slowly through liquids. Sound travels even more slowly in air because the particles are more spread out.

Table 7.1: The speed (in m s^{-1}) of sound through different substances

Substance	Speed (m s^{-1})
Rubber	60
Air	330
Water	1410
Iron	5100

Learning Ladder

Waves and motion

1. Use Figure 7.14 to identify the amplitude and frequency of a sound wave.
2. Describe the relationship between compressions and refractions and the volume and pitch of a sound wave.
3. Explain what happens to the amplitude of a sound wave when you turn up the volume on a speaker.
4. Draw a sound wave to show a:
   a high-pitch, low-volume sound.
   b low-pitch, high-volume sound.
5. Give an example of how our understanding of sound has enabled us to use it.

Conducting investigations

see page 408

1. Using your knowledge of how waves carry energy, explain why people using industrial equipment wear earphones.
2. If you were measuring the properties of sound waves, what units and equipment would you use to record the:
   a frequency?
   b loudness?
   c wavelength?
   d speed?
3. A student wrote the following conclusion to an experiment. Identify the errors and rewrite it correctly. 'The results show that when the frequency is increased, the pitch of the sound gets lower. When we turn the volume up, the amplitude of the sound wave remains the same.'
4. You undertake an investigation to calculate the speed of sound. One method is to time an echo. If you were in an open area with a large building 300 metres away, you could start a stopwatch when a loud noise was made and stop it when you heard the echo. You could then calculate the speed of sound, which is how far the sound travels in 1 second. Construct a results table for data you need to record.
5. Research typical sound volumes of everyday activities. Record your findings in a table and include a reference to your sources. More information about referencing is available in the Science how-to section on page 443.

In context

Undertake research to explain the relationship between an echo and a reflection. Identify an example of when we use an echo and explain how this works. Acknowledge your source with an appropriate reference.

Success criteria

- I can model how sound waves travel.
- I can describe the properties of sound waves.

7.5 ▸ The Doppler effect

Learning intention

At the end of this lesson, I will be able to explain the Doppler effect and give examples of its applications to technology.

Key terms

constant: remains the same

Doppler effect: a change in frequency as an object moves towards or away from an observer

emit: create or put out something, such as a sound

stationary: not moving

Investigation 7.5

The Doppler effect, page 578

Content group: Sound waves

Christian Andreas Doppler was an Austrian mathematician, physicist and astronomer. His discovery of the Doppler effect in 1842 has led to many inventions, including ultrasound technology, and has enabled us to measure the expansion of the universe and to track spacecraft from Earth. The Doppler effect is true for any wave type, including sound and all electromagnetic waves.

As an object moves, we hear a change in frequency

If a stationary car uses its horn, it produces a **constant** sound at the same pitch. If you stay in the same place, it does not matter where you are in relation to the car, the frequency of the sound stays the same. In Figure 7.16, you can see that the wavelength, and therefore the frequency, is the same in all directions from a **stationary** car.

As the car comes towards you, its horn gets louder. The pitch also increases. As the car passes and then moves away from you, the pitch of the horn appears to decrease.

As the car moves towards an observer, each cycle of the wave is pushed closer together with a shorter wavelength, increasing the frequency – and the observer hears a higher pitch. As the car passes, it continues to **emit** the sound, but each cycle of the wave is more spaced out, with a longer wavelength and decreasing frequency – and the observer hears a lower pitch. This is the **Doppler effect** – the change in frequency as an object moves towards or away from an observer.

Figure 7.17 illustrates the relationship between the motion of the car, the particles in a longitudinal sound wave, and the transverse wave form for the sound, showing the frequency. You can see the:

- lower frequency (lower pitch), longer wavelength and less compressed particles behind the car
- higher frequency (higher pitch), shorter wavelength and more compressed particles in front of the car.

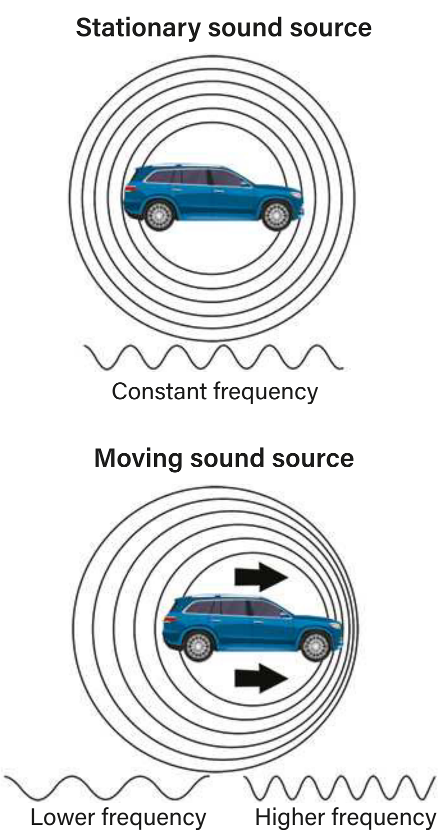


Figure 7.16: The waves in front of the moving car are squashed together (higher frequency), while behind the moving car they are further apart (lower frequency).

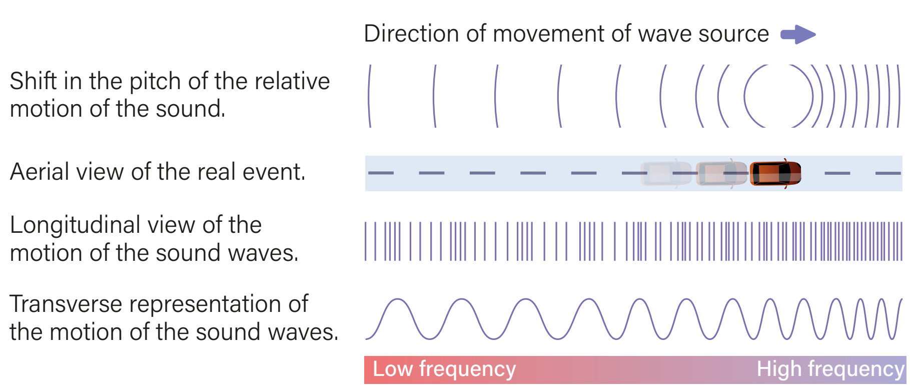


Figure 7.17: The Doppler effect

The Doppler effect has many technological uses

The Doppler effect has been used in many inventions (Table 7.2).

Figure 7.18: Police radar or speed cameras use the Doppler effect to measure the speed of cars. When the car approaches the radar, the frequency of the reflected waves is higher than the frequency of the transmitted waves; when the car is moving away, the frequency is lower. The change in frequency can be used to determine the direction and speed of the car.

Table 7.2: Some uses of the Doppler effect

Use	Description
Radar	A speed gun fires radio wave pulses (or laser light) to measure the speed of a moving car. Weather radars send out and detect returning radio waves to identify where rain is occurring and which way it is moving.
Tracking spacecraft	The movements of spacecraft away from or towards Earth can be tracked, and their speed and direction calculated.
Astronomy	The speed of stars or galaxies moving towards or away from Earth can be determined by looking at the frequency of light they emit.
Echocardio-graphy	Blood flow inside arteries and the heart can be measured to help diagnose heart disease or other heart problems such as faulty valves.
Satellite navigation	The movement of objects on Earth can be tracked from a satellite to produce navigation data.

Learning Ladder

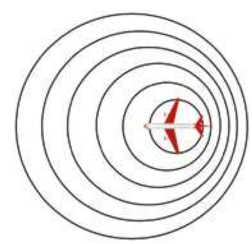
Waves and motion

1. Identify the properties of waves that change when the Doppler effect is observed.
2. **a** Describe the frequency of sound waves produced from a stationary object.
   b Compare your answer in part a with the sound waves from a moving object.
3. Explain how the Doppler effect can be useful when crossing a road.
4. Explain the Doppler effect by comparing the rarefactions and compressions of the sound wave behind a moving object and in front of a moving object. Use an illustration to support your answer.
5. Using an example, analyse an impact of the Doppler effect on society.

Conducting investigations

see page 408

1. You record some examples of the Doppler effect. One example involves riding a bicycle with a sound source (speaker) attached past a microphone to record the sound. Identify any safety precautions you should consider when conducting this investigation.
2. Identify an example of a sound analyser app that could be used to record and display the frequency of sound recorded in Question 1. Compare your app with one that someone else has identified.
3. A student observed an aeroplane pass overhead and drew the diagram on the right to show the Doppler effect. Identify the errors in the diagram and redraw it correctly.



4. Identify the evidence you would need to collect to prove that the Doppler effect is real.
5. Undertake research to find an animation of the Doppler effect. Explain how this animation demonstrates what the Doppler effect is. Ensure you reference the source of your animation. More information about referencing is available in the Science how-to section on page 443.

In context

The Doppler effect is used by deep-space radio telescopes to track spacecraft. Find out where the main telescopes for this are located, and conduct research to explain how they can keep track of spacecraft when Earth is constantly rotating.

Success criteria

- I can explain the Doppler effect.
- I can explain how the Doppler effect has useful technological applications.

7·6 ► How we hear

Learning intention

At the end of this lesson, I will be able to explain how the ear works in relation to sound.

Key terms

audiogram: a graph from a hearing test showing the frequency and loudness a patient can hear

cochlea: the organ of the inner ear that converts sound energy into nerve messages

infrasound: low-frequency sounds below 20 Hz

membrane: a thin layer of body tissue made of cells

pinna: the outer ear flap

ultrasound: high-frequency sounds above 20 kHz

Content group: Sound waves

The ear is the organ of the body that detects sound energy. It is specially adapted to funnel mechanical sound waves into the ear, and to turn them into nerve signals in the brain, which processes these as the sound we hear. We need to look after our ears, and to do that we need to understand how they work.

The ear detects vibrations in the air

Sound travels as vibrations in the air. The vibrations are detected by the ear and turned into messages that our brain interprets as sound. The ear is made up of three parts (Figure 7.19).

- The outer ear consists of the ear flap, called the **pinna**, the ear canal and the ear drum. The pinna is shaped a bit like a funnel to collect sound vibrations. Sound enters the ear canal and travels to the eardrum. The eardrum is a thin **membrane** that vibrates when sound hits it.
- The sound is transferred to the middle ear. The middle ear contains three small bones – the hammer, anvil and stirrup. These are attached to the eardrum, so when the eardrum vibrates, the bones move, transferring the sound energy through the middle ear to the inner ear.

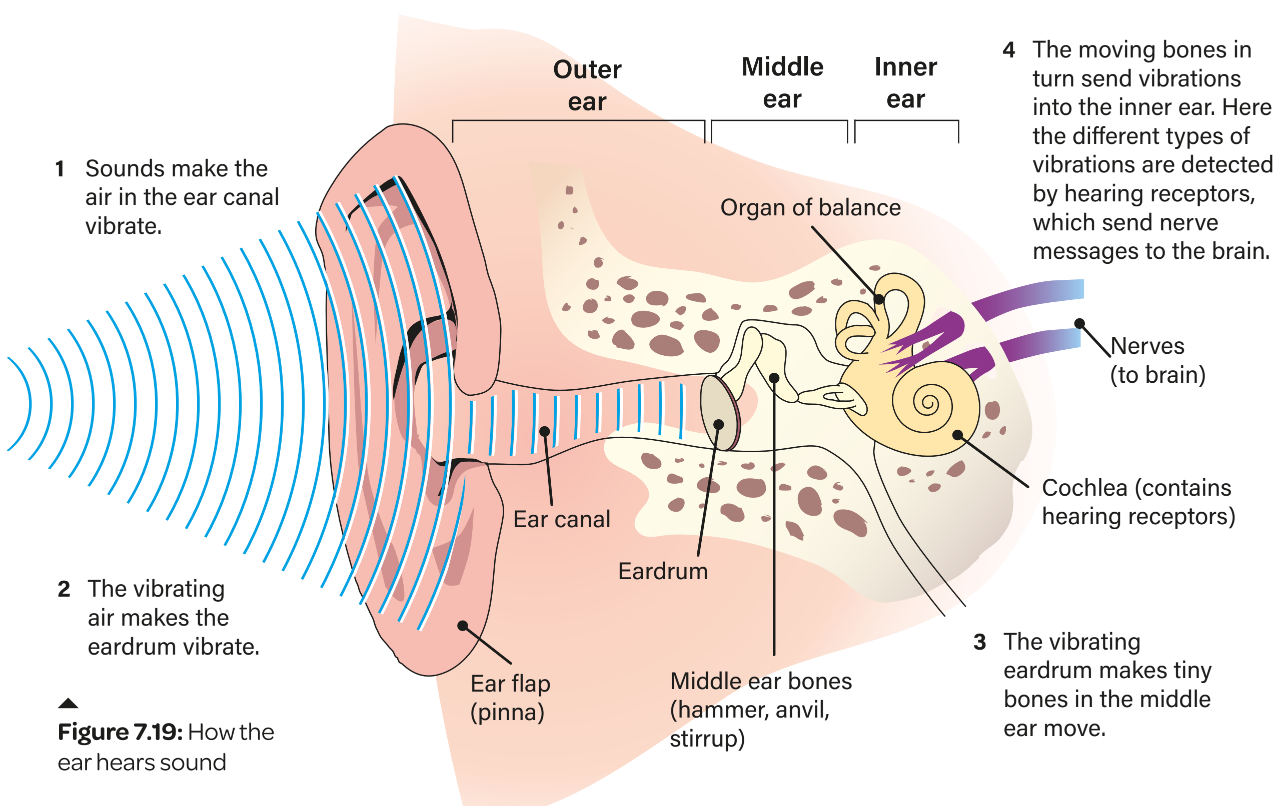


Figure 7.19: How the ear hears sound

- The inner ear contains a fluid-filled organ called the **cochlea**. The moving bones of the middle ear pass the vibrations into the fluid of the cochlea, which contains tiny hair-like receptors. The hearing receptors vibrate or move as the fluid vibrates and turn the sound energy into nerve messages that are sent through a nerve to the brain for processing. The brain interprets the sounds that we hear.

The ear also contains our balance organ, which helps us detect which way is up or down, and movement.

The ear can hear different frequencies

Humans can detect frequencies from about 20 Hz (deep bass) to 20 kHz (20 000 Hz). As we age, we become less able to hear higher frequencies, so adults can usually hear up to 15–17 kHz.

Sounds lower than 20 Hz are called **infrasounds** and sounds higher than 20 kHz are called **ultrasounds**. Some animals can hear different frequencies from humans; for example, bats and dolphins can hear ultrasounds up to 160 kHz.

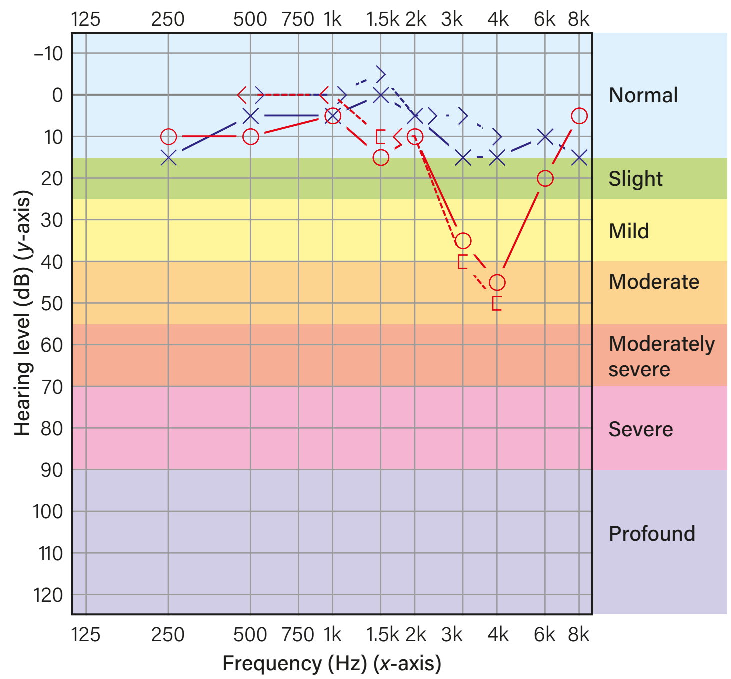


Figure 7.20: Does this audiogram show a hearing loss for this person? The red line is the right ear; the blue line is the left ear.

An audiogram is used in a hearing test

In a hearing test, you listen to sounds of different frequencies at different volumes to determine what you can and cannot hear. The test is for frequencies of between 250 and 8000 Hz, as that is the main range for speech. The results of a hearing test are shown as an **audiogram** – a graph that shows how loud a sound needs to be at different frequencies for you to hear it. Figure 7.20 is an example of an audiogram. Frequency is on the *x*-axis and loudness is on the *y*-axis. The shaded sections show where the lines should be to have normal hearing. If the lines for either ear drop below the normal section, then there is hearing loss.

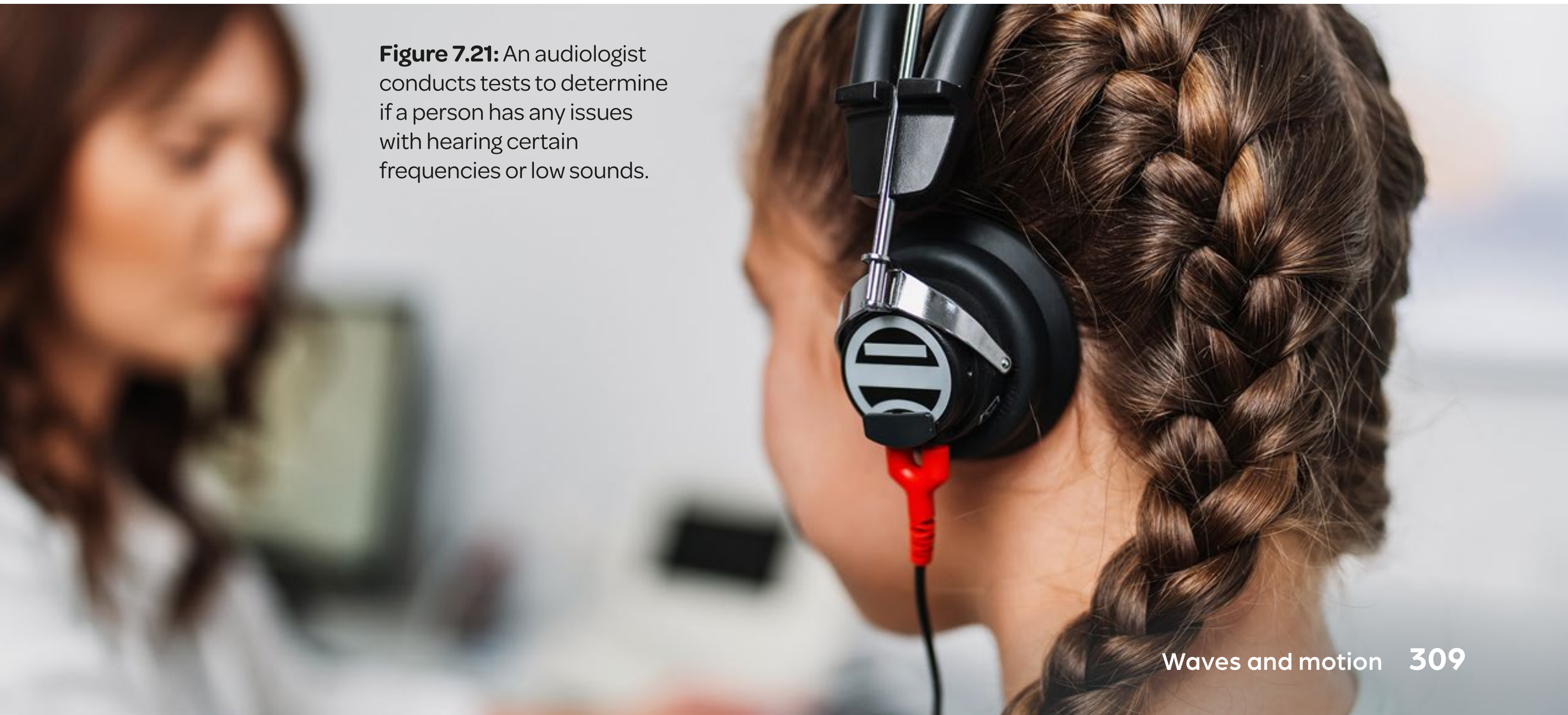


Figure 7.21: An audiologist conducts tests to determine if a person has any issues with hearing certain frequencies or low sounds.

Loud sounds can damage the ear

Sound levels are measured in decibels (dB). Loud sounds can damage the sensitive receptors in the middle ear, especially if a person is exposed to loud sounds for long periods of time. People who work in a noisy environment are more at risk of hearing loss. Loud music can also cause damage over time, with the extent of hearing loss related to the length of exposure. Table 7.3 outlines some typical sounds, their loudness, and when damage may be caused. Remember that sound is energy, and too much energy can break things!

The experience of ringing ears after attending a rock concert shows that damage has been done to your inner ear. How long you are exposed to a sound and how close you are to the source will determine whether there will be damage. Recommended exposure times to loud sounds without hearing protection are shown in Table 7.4.

Table 7.4: Typical recommended maximum exposure times to avoid hearing damage

Loudness (dB)	Maximum exposure time
106	3.75 min
103	7.5 min
100	15 min
97	30 min
94	1 h
91	2 h
88	4 h
8	8 h

Table 7.3: Effects on the ear of various sounds

Sound	Loudness (dB)	Effect on the ear
Fireworks, explosion	150	Eardrum can burst; damage to inner ear receptors
Aeroplane taking off	140	Very painful
Racing car, jet engine	130	Painful
Ambulance siren, chainsaw	120	Painful, non-reversible damage above this level
Power saw, jackhammer, motorcycle	110	Immediate damage to ears
Night club music, loud concert, train	100	Danger, harmful sounds
Heavy traffic, electric drill	90	Sound above this level starts to cause damage
Vacuum cleaner, noisy restaurant	80	Annoying sound level
Noisy party, washing machine spinning	70	Hard to stay in room for long periods
School playground, heavy rain	60	Loud sound
Normal conversation, electric toothbrush	50	
Quiet office or residential area, light rain	40	Quiet sound
Whispering	30	Very quiet sound
Leaves rustling, mosquito buzzing	20	
Normal breathing	10	Just able to hear sound

Figure 7.22: Ear protection is essential when using noisy tools such as an electric saw.

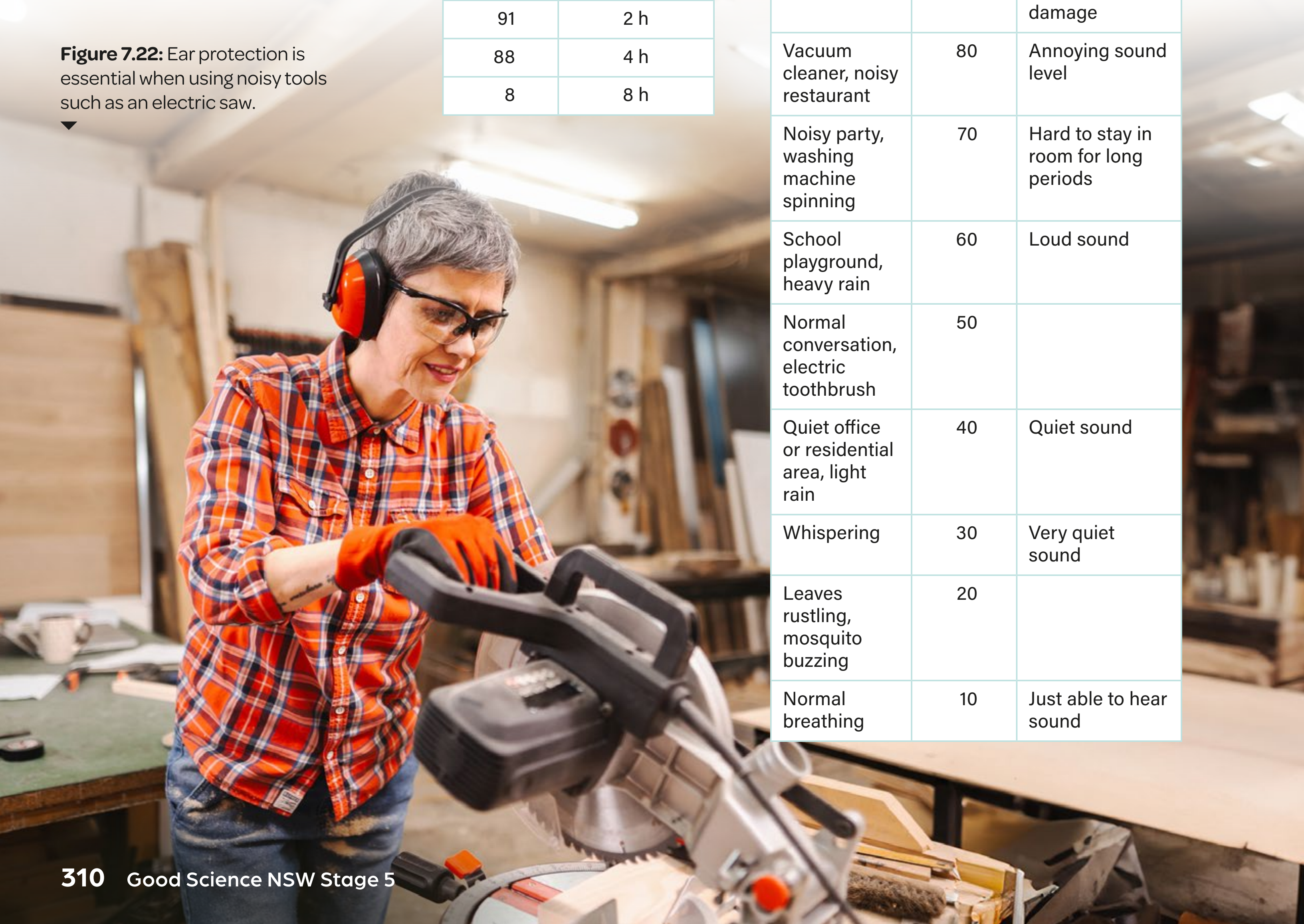


Figure 7.23: A cochlear implant is a type of hearing aid that directly stimulates the nerve ends of the cochlea.

Table 7.5: Different frequencies of sound that animals can hear

Animal	Approximate frequency range (Hz)
Elephant	16–12 000
Human	64–23 000
Dog	67–45 000
Cat	45–64 000
Mouse	1000–91 000
Bat	2000–110 000
Beluga whale	1000–120 000
Dolphin	75–150 000
Parakeet	200–8500
Owl	200–12 000

Animals can hear different frequencies of sound (Table 7.5).

Hearing aids help people with ear damage to hear

A hearing aid is a small electronic device that can make sounds louder, screen out unwanted frequencies, and play them into the ear to help people hear better. A hearing aid is usually used when the ear is damaged and the person either cannot hear some frequencies or cannot hear low sounds. Damage can occur to the middle ear (e.g. to the three small bones) or to the inner ear if the receptors are damaged from loud sounds.

A cochlear implant is a type of hearing aid that is surgically implanted into the cochlea of the inner ear. It works when sound is collected by a receiver close to the ear canal. The receiver processes the sound and turns it into electronic signals. The signals are sent to a transmitter on the skull, which sends the messages to the cochlear implant. The implant directly stimulates the nerve endings that send messages to the brain, allowing the wearer to hear some sounds.

Learning Ladder

Waves and motion

1. List the features of the:
   - a outer ear.
   - b middle ear.
   - c inner ear.
2. Describe the frequencies that humans can usually hear and how they change with age.
3. Explain how the ear transfers the energy from a sound wave into the nerve and brain.
4. Demonstrate with examples how louder sounds can damage a person's hearing.
5. Discuss how our understanding of the loudness of sound waves has affected how we protect people's hearing. Use examples to justify your answer.

Processing data and information see page 412

1. The audiogram in Figure 7.20 shows hearing loss in the right ear.
   - a Classify the level of hearing loss.
   - b Where the loss is greatest, identify the frequency and loudness of the sound played for the patient to hear it.
2. Construct a visual representation of the data from Table 7.3 about sound levels. Include images, units for values, and colours to indicate the danger levels of these sounds.
3. Humans can hear a maximum of 20 kHz. Dolphins can hear up to 160 kHz.
   - a Convert each value into hertz.
   - b Calculate how many times higher the frequency of sound that a dolphin can hear is than the frequency of sound that a human can hear.
4. Mei says that she can go to a rock concert and listen to the very loud music for up to 1.5 hours without any damage to her hearing. Use data to justify whether Mei is correct. Estimate how long she could listen for without her hearing being damaged.
5. Design a sound booth that would help to improve the accuracy of data collected in an audiogram test.

In context

Use a sound meter or a mobile phone app to investigate the volume of everyday sounds. Construct a table to record your results. Compare them to those in Table 7.3 and suggest reasons for any differences.

Success criteria

- I can explain how the ear responds to sound.
- I can explain the features of sound waves and how they are related to hearing.

7.7 ▸ First Nations Peoples' use of sound energy

Figure 7.24: Many Aboriginal and Torres Strait Islander Peoples use clapsticks to create music.

Learning intention

At the end of this lesson, I will be able to outline examples of how the materials Aboriginal and Torres Strait Islander Peoples use to make traditional musical and communication instruments affect their sound.

Key terms

aerophone: an instrument that produces sound by causing air to vibrate

bore: the hollow in the centre of a tube

idiophone: an instrument that produces sound through vibrating itself

membranophone: an instrument that produces sound through a vibrating, stretched membrane

Content group: Sound waves

Aboriginal and Torres Strait Islander Peoples have invented and used instruments for many thousands of years. The instruments have been used for both social and cultural reasons, including to represent and communicate important knowledge through music, song and dance. Different instruments are made from materials that come from different locations, which contributes to their unique and varied sounds.

Musical instruments create special sounds

Musical instruments generate sounds of a particular frequency and amplitude by vibrating. A combination of frequencies is produced that affects the tone and makes the sound richer or more complex. The complexity of the sound is also influenced by the type of material used to construct the instrument.

Vibrations are produced by playing the instrument; different notes are produced by altering the frequency, and different volumes are produced by adjusting the amplitude of the waves.

Aboriginal and Torres Strait Islander Peoples in Australia have created three types of instruments: idiophones, membranophones and aerophones. Within each of these types is a wide variety of instruments whose sound is determined by the different materials used in making them.

Idiophones make the instrument vibrate

Idiophones are percussion instruments that create sound when the instrument vibrates.

Wooden sticks, often known as clapsticks, are struck together. The type and hardness of the wood, the length and shape of the sticks, and how hard they are hit, all affect the frequency and amplitude of the sound waves produced.

- On the Tiwi Islands of the Northern Territory, sticks are made from ironwood (*kartukuni*), which creates a unique sound.
- In western Victoria, sticks are made with rounded ends that produce a musical sound that travels very long distances.
- In southern Arnhem Land, in the Northern Territory, the Ngukurr Peoples make sticks of different lengths that produce different musical frequencies.
- Some Aboriginal and Torres Strait Islander Peoples use boomerangs as clapsticks, by clicking or rattling two boomerangs together. These are often called clapping boomerangs.
- Some Aboriginal and Torres Strait Islander Peoples use percussion tubes as idiophones. The hollow logs are hit with a stick to create sound. The frequency depends on the length of the log and the type of wood used. The longer the log, the lower the frequency.
- Some people make rattles and shakers. For example, the Yupungathi Peoples of western Cape York Peninsula make rattles with strings of shells. Torres Strait Islander Peoples make *kulaps*, or rattles made by threading seed pods of the matchbox vine onto lengths of twine.

Membranophones make a stretched membrane vibrate

Membranophones produce sound through a vibrating, stretched membrane, and are a type of drum. Sounds are produced by stroking the membrane by hand or

▲ **Figure 7.25:** The membrane on a drum is usually made of stretched animal skin.

with a stick. Often, the skin of the drum is made of the skin of an animal, such as goanna. The frequency of the sound produced is changed by the size of the wooden tube, the type of wood used and the tightness of the membrane.

On the mid-north coast of New South Wales, the Gumbaynggir Peoples make drums (*buljirr*) using possum skin as the membrane. From central Queensland to the New South Wales border, the Murawari Peoples use a drum made from kangaroo hide and stuffed with possum fur as a percussive instrument.

Aerophones make the air vibrate

Aerophones produce sound by causing the air to vibrate. The many types of aerophones include whistles, trumpets, tubes (didjeridus) and leaves.

Leaf blowing involves placing a leaf between the lips and blowing air across the leaf's surface. As the leaf vibrates against the lips, sound is produced. Adjusting the lips can produce different frequencies and volumes. In mainland Australia, eucalyptus (gum) leaves are used as leaf instruments.

Tube instruments work by blowing air over the top of the tube. The longer the tube, the lower the frequency. On the Mer Islands of the Torres Strait, flutes are made from different lengths of bamboo or reeds, and sound vibrations are produced by blowing air over the top of the open tubes. The Mer Islander Peoples also make whistles (*mersok*) from empty seed pods, blowing air over the top of the open pods to create musical sounds.

Figure 7.26: The didjeridu is made from the hollow trunk of a eucalyptus tree.

The best-known musical aerophone in Australia, originally found only in northern areas, is commonly known as the didjeridu. These instruments have many different names, depending on their location. For example, the Yolgnu Peoples of eastern Arnhem Land called the instrument a *yidaki*.

When using a didjeridu, the sound is produced by the player's lips. Didjeridu players create sound while breathing both in and out continually. The player controls the frequency of the sound with their lips, vocal cords, mouth and tongue. When air is pushed from the mouth into the didjeridu interior (the **bore**), a distinctive sound is produced. Every didjeridu is different; the type of the wood, the length of the tube and the shape of the interior all change the sound. A didjeridu is made from the main trunk of a eucalyptus tree, where the interior of the tube is eaten out by termites. This means the shape and width of the bore varies in each case, changing the frequency and amplitude of the sound in each unique instrument. Table 7.6 shows how the frequency of the sound produced changes as the length of the didjeridu changes.

Table 7.6: The effect of didjeridu length on the frequency of the sound produced

Frequency (Hz)	Length (mm)
41.2	2087
49	1755
55	1564
65.4	1315
69.3	1241
77.8	1106
87.3	985
98	878
110	782
123.5	696

Figure 7.27: Hardwood clapsticks, or musicsticks, are idiophones.

Learning Ladder

Waves and motion

1. Construct a table and classify the following instruments as idiophones, membranophones or aerophones: percussion tube, *kulap*, didjeridu, leaf, boomerang, *mersok*, clapstick, *buljirr,* shaker.
2. Compare how an idiophone and an aerophone produce sound waves.
3. Explain reasons why Aboriginal and Torres Strait Islander Peoples use musical instruments.
4. Using the information provided, what can you conclude about the length of an instrument and the frequency of the soundwaves produced? Provide at least two examples.
5. Propose ways in which instruments have affected Aboriginal and Torres Strait Islander Peoples' lives.

Processing data and information

see page 412

1. Copy Table 7.6 and add a column for wavelength. Calculate the wavelength for each didjeridu length using the speed of sound in air of 343 m s^{-1} and the formula $v = f\lambda$. Remember to show the unit for wavelength.
2. Using Table 7.6, construct a graph to show the relationship between the length of a didjeridu and the frequency of the sound produced. (More information about drawing graphs is available in the Science how-to section on pages 457–61.) Use your graph to describe the relationship between the length of the didjeridu and the frequency of its sound.
3. Use your answers from Question 1 to refute or support the following statement: 'With a didjeridu, when the frequency gets higher, the wavelength gets shorter.'
4. Describe how you could record the frequency of a range of Aboriginal and Torres Strait Islander Peoples' instruments.

In context

Using the same scientific principles, construct an instrument that can produce sound in the same way as a traditional Aboriginal and Torres Strait Islander instrument. Present the instrument to the class and explain the similarities and differences between it and an equivalent instrument that an Aboriginal or Torres Strait Islander person might construct.

Success criteria

- I can outline examples of how the materials used in Aboriginal and Torres Strait Islander Peoples' musical and communications instruments affect the instruments' sound energy.
- I can outline features and uses of traditional Aboriginal and Torres Strait Islander Peoples' musical and communications instruments.

7·8 ▸ Medical uses of sound

Learning intention

At the end of this lesson, I will be able to describe examples of the medical uses of sound.

Key terms

neurosurgeon: a specialist doctor who operates on the brain and nervous system

receiver: a device that receives or detects sound

reflect: send back sound or light without absorbing it

therapeutic: ways of healing

transmitter: a device that produces or transmits sound

Content group: Sound waves

Sound has beneficial applications in medicine. Stethoscopes, which are used to listen to the sound of someone's heartbeat, were first used in the early 19th century. Sound can help to heal injuries, measure blood flow and make live, moving images of the inside of the human body. Sound waves can be focused deep inside the body to stop bleeding; they can help doctors to administer drugs to specific parts of the body; and they can prevent the impacts of bacterial infections, and more!

Ultrasound can make images inside the body

Ultrasound is high-frequency sound waves (above 20 kHz) used in medical diagnostics to visualise internal body parts and to monitor the development of unborn babies. An ultrasound machine directs the high-frequency sound waves into the body. The sound **reflects** or echoes off the different tissue layers inside the body, and the echoes are recorded as an image that can be seen on a screen. The ultrasound probe is called a transducer and produces sound at a level of from 2 to 8 megahertz (MHz).

▲ **Figure 7.28:** Ultrasound can produce live and moving images of an unborn baby.

Ultrasound has therapeutic uses

Therapeutic (for therapy or healing) uses of ultrasound do not produce images and are usually of a lower frequency (700 kHz to 3 MHz). Ultrasound can be used therapeutically to:

- help increase blood flow to an injury, to speed up healing
- break down blot clots in muscle
- push or heat tissues
- help push and deliver drugs to certain parts of the body.

New uses are still being invented. For example, ultrasound can be used to destroy abnormal tissue such as tumours without surgery, which enables patients to recover from treatment much more quickly.

A Doppler flow meter measures blood flow

A Doppler flow meter measures, in real time, how fast blood flows around the body. Placed directly on the skin, the **transmitter** produces continuous sound waves of frequencies between 500 kHz and 1 MHz. The sound waves pass into the body and reflect off moving red blood cells back to the **receiver**. The frequency of the sound changes because of the Doppler effect. This is because the blood cells are moving but the detector (or 'observer') is not. The receiver uses the change in frequency to calculate the speed of movement of the blood cells. This can tell us where arteries are narrowed or blocked, causing the blood to slow down to get through. The Doppler meter can also detect an unborn baby's heart at only 8–10 weeks old.

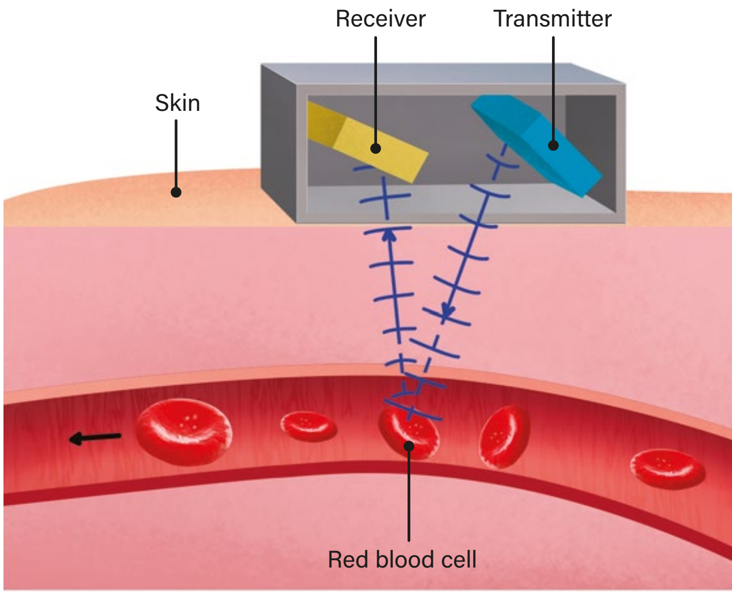


Figure 7.29: A Doppler flow meter bounces sound off moving red blood cells to measure their speed and the flow of blood.

Sound can help in removing brain tumours

Neurosurgeons developed the cavitron ultrasonic surgical aspirator (Figure 7.30), which is used to operate on cancerous tumours in the brain that would otherwise be almost impossible to remove. A probe that produces sound waves at 20–60 kHz is inserted into the tumour. The sound waves create vibrations, which break up the cancer cells while mixing in salt water (saline). The broken cells are then vacuumed out through the probe without damaging the surrounding healthy brain cells.

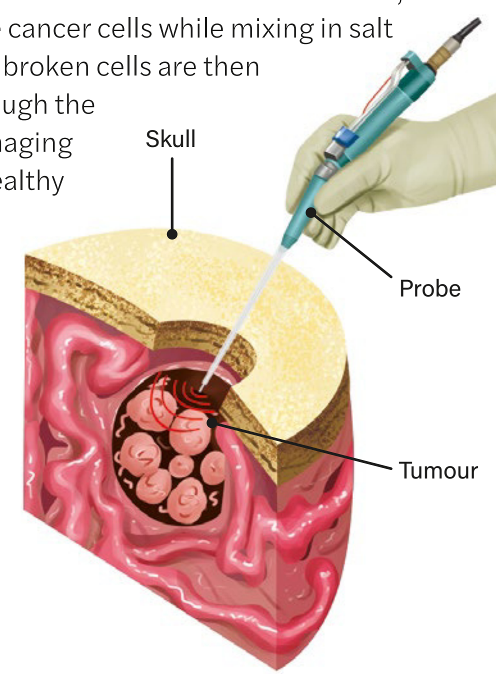


Figure 7.30: A cavitron ultrasonic surgical aspirator makes removing cancer cells a much safer procedure for a patient.

Learning Ladder

Waves and motion

1. Identify the minimum frequency required for sound to be classified as ultrasound.
2. Compare the sound waves used for ultrasound imaging and for therapeutic treatments. What is the main difference between the sounds?
3. Explain two applications of sound waves in medicine.
4. Explain what 'reflection of sound waves' means, and describe why it is important in the use of medical sound devices.
5. Give two examples of how the use of sound in medicine has affected people's health and wellbeing.

Processing data and information *see page 412*

1. A person having an ultrasound treatment suggests that they can hear the sound from the transducer used to apply the sound to their body. Using your knowledge of sound, propose whether they are correct, and justify your answer.
2. Construct a table that shows the frequency of waves used for the Doppler flow meter, ultrasound imaging, therapeutic ultrasound and the cavitron ultrasonic surgical aspirator. List their uses, from the lowest to the highest frequency range. More information about constructing tables is available in the Science how-to section on pages 412–13.
3. We know that 1 kHz = 1000 Hz. Ultrasound imaging uses frequencies in the MHz range. Define what 1 megahertz is equal to.
4. In ultrasound imaging, it is difficult to make clear images of organs that are deep inside the body. Using your knowledge of sound as a form of energy, explain why the image becomes less clear as sound travels more deeply into the body. Propose a way to increase the depth of imaging.
5. Propose why applying a gel between the ultrasound transducer and the skin improves the quality of the ultrasound data and the results.

In context

There are many medical uses of sound. Identify a use of sound in another industry and explain how this benefits society.

Success criteria

- I can give examples of how sound is used in medicine.

7.9 ► Light waves

Learning intention

At the end of this lesson, I will be able to describe the properties of light and its applications.

Key terms

absorption: when light is not reflected by a substance but instead is turned into energy

angle of incidence: the angle at which light hits a surface

angle of reflection: the angle at which light reflects from a surface

concave: curved or rounded inwards

convex: curved or rounded outwards

normal: a line at right angles to the surface of a substance

opaque: a material that does not allow any light to pass through

reflection: when light is bounced off a surface

refraction: when light is bent as it passes from one substance to another

scattering: light rays are randomly reflected in many directions

translucent: a material that allows some light to pass through

transparent: a material that allows light to pass through

Investigation 7.9A

The law of reflection, page 579

Investigation 7.9B

Refraction, page 581

Content group: Light waves

Understanding the properties of light allows us to use it in many different devices, including telescopes, spectacles, torches and solar panels.

Light can pass through some substances

Materials that allow light to pass through are known as **transparent** (e.g. glass). **Translucent** materials allow some light to pass through (e.g. frosted glass). **Opaque** materials do not allow any light to pass through and either **reflect** or **absorb** it (e.g. aluminium foil).

These properties of light allow us to use different materials for different purposes. For example, a solar panel has a transparent glass surface that light can pass through. The components of the solar panel absorb the light and convert it to electrical energy. A solar hot water heater has black opaque pipes that absorb light energy from the Sun, transforming it into heat energy that warms the water inside the pipes.

Mirrors reflect light

Light is reflected off a smooth shiny surface such as water or a mirror. When all light is reflected, we get a clear image. This is how a mirror works. Mirrors have a shiny coating on the back of a sheet of glass to reflect the light, creating an image.

The law of reflection states that the angle at which light bounces off the surface (**angle of reflection**, *r*) is the same as the angle at which it strikes the surface (**angle of incidence**, *i*) (Figure 7.31). The light going towards the surface is the incident ray. The light that bounces off it is the reflected ray. The angle of incidence and the angle of reflection are always equal and are measured from the **normal** – an imaginary line at right angles to the surface.

Reflection can be used in many devices, including endoscopes (for looking inside the body) and optic fibres.

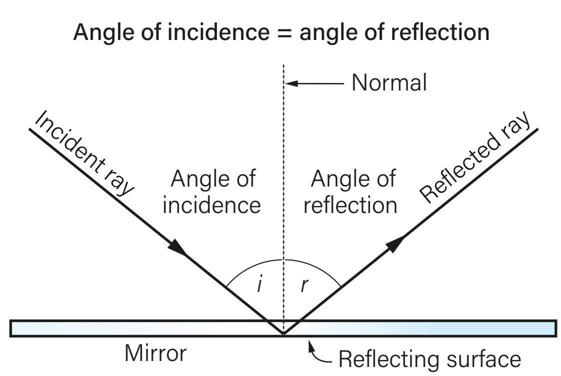


Figure 7.31: The law of reflection in a flat (plane) mirror: $i = r$.

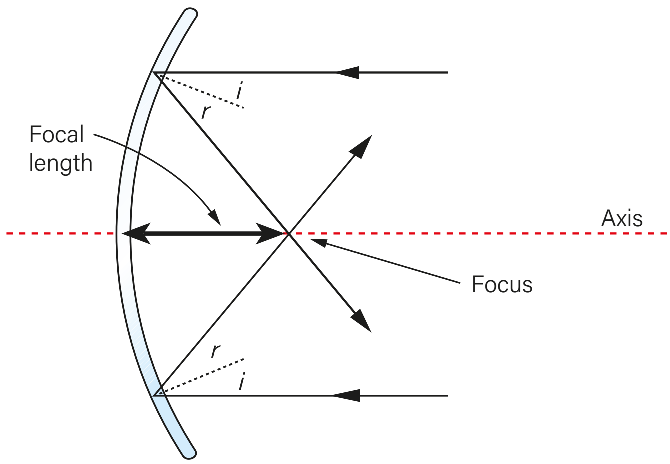


Figure 7.32: A concave mirror reflects light inwards to a focus and still obeys the law of reflection.

Curved mirrors reflect light

Even if a mirror is curved, $i = r$. With a curved mirror, the normal is drawn at right angles to the surface at the point where the light hits the mirror.

There are two types of curved mirrors.

- A **concave** mirror curves inwards (Figure 7.32). This mirror focuses light rays at a point where they cross over – the focus.
- A **convex** mirror curves outwards and reflects light rays away from each other. These mirrors are used to help us see around corners, such as in car parks or other locations where they can help to prevent accidents.

Concave mirrors are used in torches. When a light bulb is placed at the focus of a concave mirror, the light rays hit the mirror and bounce off, creating a beam of light all going in one direction, as shown in Figure 7.33. Concave mirrors are also used in reflecting telescopes to focus light from far away to create images.

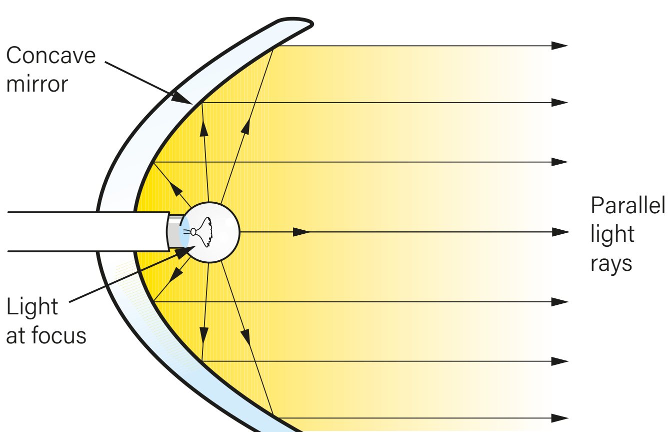


Figure 7.33: A torch reflects a beam of parallel light rays travelling in one direction.

Light refracts from one substance to another

Light travels at different speeds in different mediums. So, when light passes from one medium to another (e.g. from air to water), it usually **refracts**, or bends (Figure 7.34). If you have tried to use a stick to poke something on the bottom of a pond, you may have noticed that the stick looks bent and often does not hit the object you are aiming for.

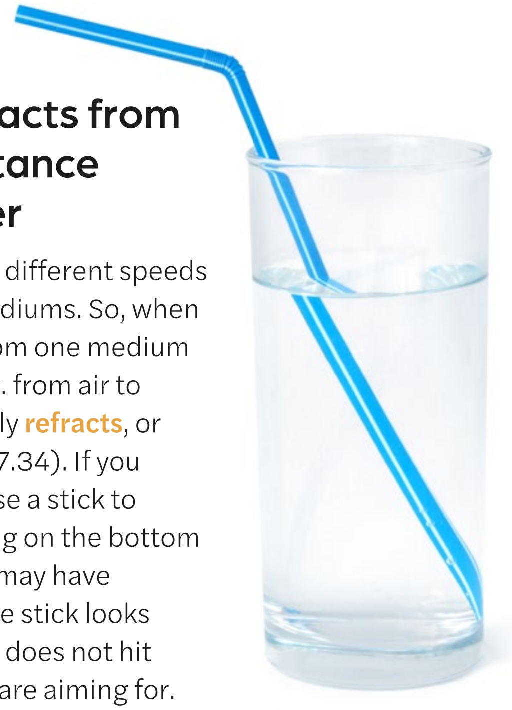


Figure 7.34: A straw in a glass of water appears to be bent because of refraction.

Figure 7.35 shows light entering and leaving a glass block. When refraction occurs, the angles of incidence and refraction are *not* always equal. When light enters glass from the air, it slows down and bends towards the normal. The angle of refraction is less than the angle of incidence. When light exits the glass into the air, it speeds up and bends away from the normal. In this case, the angle of refraction is more than the angle of incidence.

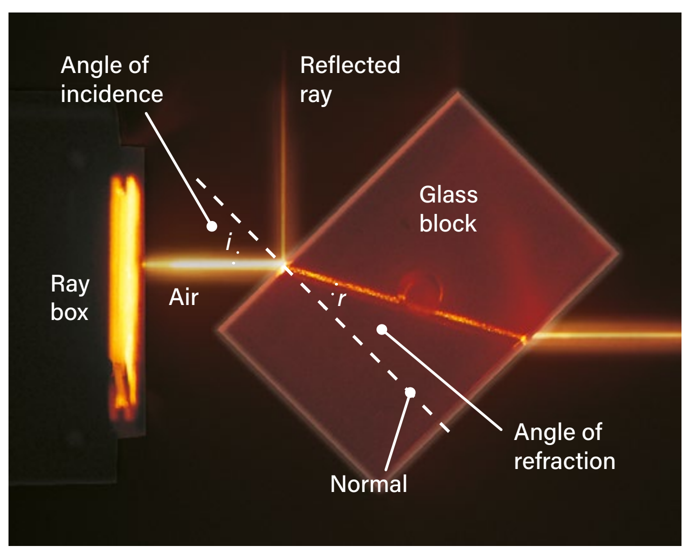


Figure 7.35: Refraction of light occurs as it enters and exits a glass block. Light bends towards the normal, and *r* is smaller than *i*.

Table 7.7 shows the speed of light in different substances. It also shows the refractive index, which indicates how much light bends when it enters a substance from the air. Air has a refractive index of 1. The higher the refractive index, the more light bends when entering that substance from the air.

Table 7.7: The speed of light in different substances

Substance	Refractive index	Speed of light ($\times 10^3$ m s^{-1})
Air	1.00	3.0
Water	1.33	2.3
Perspex	2.0	2.0
Glass	2.0	2.0
Diamond	2.42	1.2

Lenses bend and focus light

Convex lenses bulge outwards and make light rays converge (get closer together). The light rays meet at the focal point. Concave lenses curve inwards and make light rays diverge (spread out) (Figure 7.36). A thicker convex lens bends light more and focuses it closer, with a shorter focal length. A thicker concave lens spreads light out more than a thinner one does.

Convex lenses make objects look bigger. Magnifying glasses, camera lenses and some telescopes use convex lenses. Concave lenses make objects look smaller. Concave lenses are used in spy holes in doors, and in street lights to spread the light out. Both convex and concave lenses are used in spectacles to correct problems with vision.

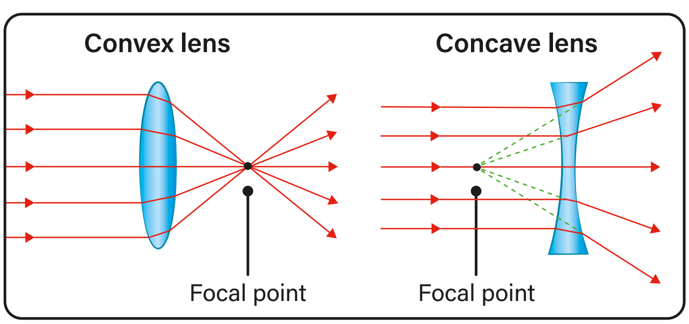


Figure 7.36: A convex lens makes light rays converge at a single point, the focal point. A concave lens makes rays diverge.

Refraction can separate white light into colours

Refraction can be used to separate visible light into its colours. Each colour has a different wavelength. Red has the longest wavelength (700 nanometres, nm) and the highest speed, and violet has the shortest wavelength (380 nm) and the lowest speed. When white light enters a prism, the different colours are refracted by different amounts (Figure 7.37). Light of a shorter wavelength and lower speed is refracted more than light of a longer wavelength and higher speed. This means that when the light emerges from the prism, it has been separated into its colours.

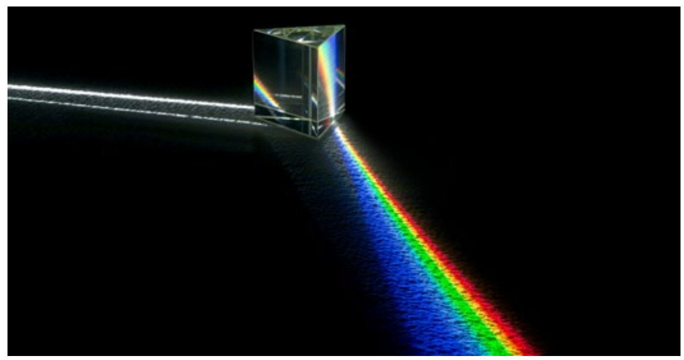


Figure 7.37: A glass prism can separate visible light into colours.

Scattered light makes the sky blue and sunsets red

When light bounces off the tiny particles of dust, smoke, pollution or particles in the air, it **scatters** in all directions. If you shine a torch through dust or fog, you can see the light beam because light is scattered off the particles to your eye.

Earth's atmosphere contains many particles that we cannot see. As light from the Sun hits these particles, some of the blue light is scattered up in the atmosphere and we see this blue light as the sky.

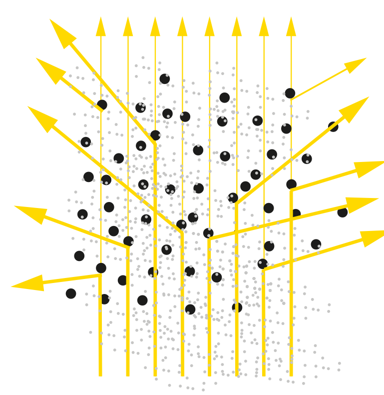
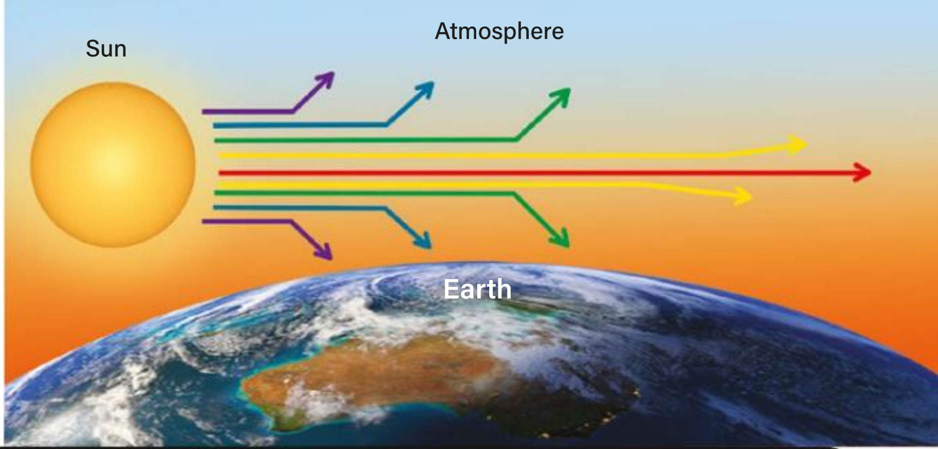


Figure 7.38: Scattering of light occurs when light hits particles (e.g. smoke) in the air.

When the Sun is low in the afternoon, the light has to travel further through the dust in the atmosphere. More blue light is scattered away in all directions, but red and orange light is less scattered and so the sky looks reddish to us. Sunsets can look more colourful on polluted days because there are more particles to scatter the blue light away (Figure 7.39).

Figure 7.39: Sunsets occur when blue light is scattered more than red light.



Learning Ladder

Waves and motion

1. Match the following features of waves with their explanations by writing them into your book.

Feature	Explanation
Refraction	Bouncing of light off particles in the atmosphere or air
Reflection	Bending of light as it passes from one substance to another
Scattering	Bouncing of light off a surface
Absorption	Light hitting a surface and turning it into energy

2. **a** Outline the law of reflection.
   b Describe how the law of reflection applies to a plane mirror. Explain the normal, incident ray, reflected ray, and the angles of incidence and reflection.
3. Copy and complete the following table, adding extra rows as needed. Include at least one example for each type of mirror or lens.

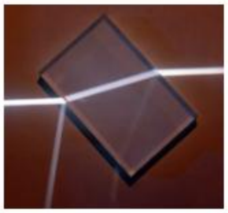
Type of lens or mirror	Examples of use	Property of light used

4. Draw diagrams including light rays to compare:
   a convex and concave lenses.
   b convex and concave mirrors.
   c plane mirror and wooden surface.
   d translucent and transparent substances.
   e the refraction of light when it goes from air to water and air to glass. Refer to Table 7.7 for help in answering.
5. Analyse the impact of lenses or mirrors on society, referring to some examples of inventions.

Conducting investigations

see page 408

1. Propose reasons why you should never point a telescope at the Sun.
2. Place a coin in an empty mug, and look at it from an angle so that you can just see the edge of the coin. Have a partner slowly pour water into the mug. Record and explain your observations using a diagram to demonstrate the light rays both with and without water in the mug.
3. A ray of light was shone through a glass block, as shown. The light ray is entering from the left. Draw a scientific diagram to represent the experiment and label all the relevant angles and rays.



4. Consider Table 7.7.
   a What can you conclude about the relationship between the speed of light and the refractive index?
   b Construct a hypothesis about the refractive index and the density of the substance.
5. Undertake research to construct a labelled diagram to demonstrate why the sky appears blue. Be sure to acknowledge the source of your information. More information about referencing is available in the Science how-to section on page 443.

In context

Optic fibres are one of the fastest ways to get data from one location to another, including over long distances (e.g. internet cables between countries). Investigate how optic fibres work, and explain this using your knowledge of the properties of light.

Success criteria

- I can describe the properties of light, including absorption, reflection, refraction and scattering.
- I can describe and explain the applications of light in everyday life.

7·10 ▸ How we see

Learning intention

At the end of this lesson, I will be able to describe how the eye responds to light.

Key terms

cones: light receptors in the retina that detect coloured light

eye: an organ of the body that detects light

long-sighted: a condition of the eye where light focuses behind the retina

retina: the inside, back layer of the eyeball that is made of light receptors

rods: light receptors in the retina that detect shades of light and allow us to see in black and white

short-sighted: a condition of the eye where light focuses in front of the retina

Investigation 7.10

Eye dissection, page 583

Content group: Light waves

Imagine crossing the road without being able either to see objects moving or to work out how distant they are! The human eye can make clear images of our surroundings and detect the colours in visible light, so that we see colourful images. Having two eyes means we can see three-dimensional images and judge distances.

The lens focuses light

The parts of the **eye** are shown in Figure 7.40.

- A transparent flexible lens focuses light.
- The lens muscles pull the lens to change its shape.
- The cornea is a clear protective layer on the front of the eye.
- The pupil is the hole in the centre of the eye through which light enters.
- The iris is the coloured part at the front of the eye. The iris can change size to control the amount of light that enters the eye.
- Eyelids are flaps of skin that open and close over the eye. They protect the eye and wipe away dust when we blink.
- The inside, back layer of the eyeball is the **retina** and is made of light receptors.
- The fovea is a small spot, sometimes called the 'blind spot', where the optic nerve connects and has no light receptors.
- The optic nerve connects the light receptors in the retina to the brain.

When light enters the eye, it is focused by the lens to form an image on the retina. The retina has light receptors that detect the light and send the information to the brain to create images of what we see.

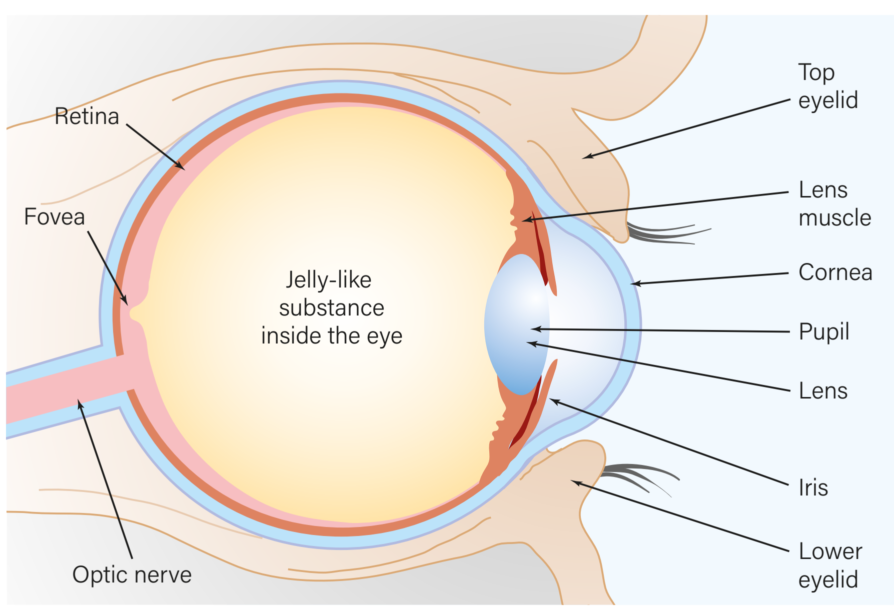


Figure 7.40: The eye has many parts that work together to allow us to see.

The lens changes shape to focus on objects

When light enters through the eye, it is focused onto the retina to create an image. The retina is like a screen made of light receptors. The lens changes shape to focus on objects that are either near or far away. The lens muscles pull the lens to make it thinner when viewing something far away. They relax to allow the lens to go back to a thicker position for viewing objects that are close (Figure 7.41).

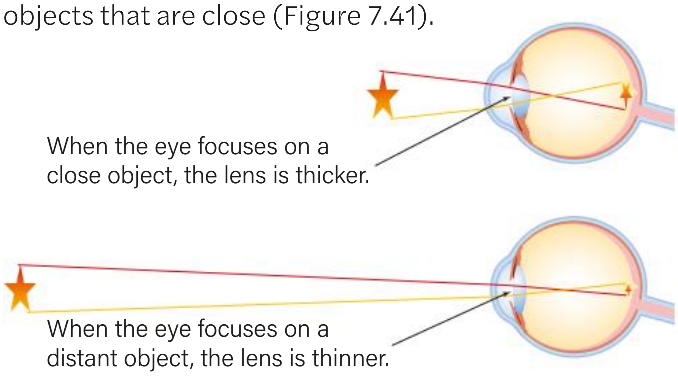


Figure 7.41: Viewing objects that are close or far way requires the lens to change shape and focus the light onto the retina.

Lenses are used to correct eyesight

Many people have eyesight problems. Especially as people age, the lens gets harder and less flexible or the muscles that control the lenses weaken and do not change the lens shape as easily to focus light. People can be short-sighted or long-sighted.

People who are **short-sighted** cannot focus on objects far away. The light focuses in front of the retina instead of on it. To fix this, a concave lens is added in front of the eye to spread the light out more so the image forms on the retina, as shown in Figure 7.42. Another cause of short-sightedness is when the eyeball is too long.

People who are **long-sighted** cannot focus on objects that are close. The light focuses behind the retina instead of on it. To fix this, a convex lens is added in front of the eye to bend the light more so that it forms the image on the retina. Another cause of long-sightedness is when the eyeball is too short.

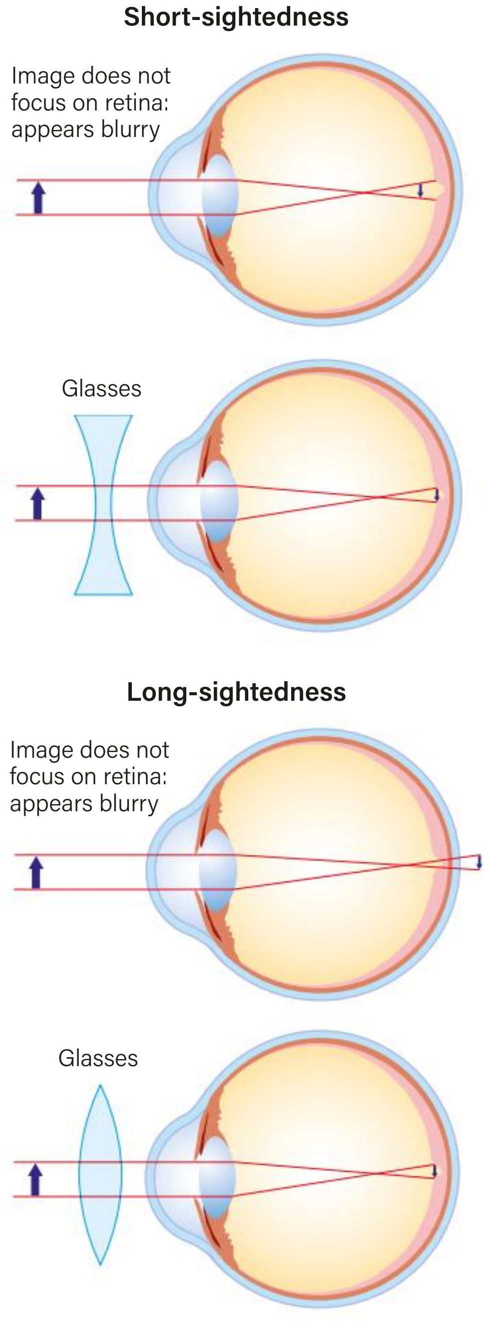


Figure 7.42: Adding lenses in front of the eye can correct short- and long-sightedness.

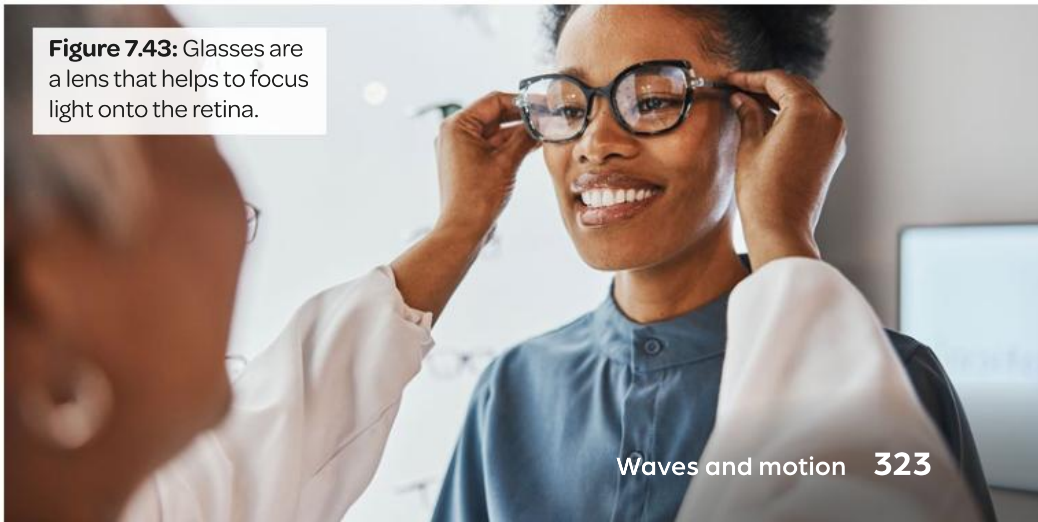
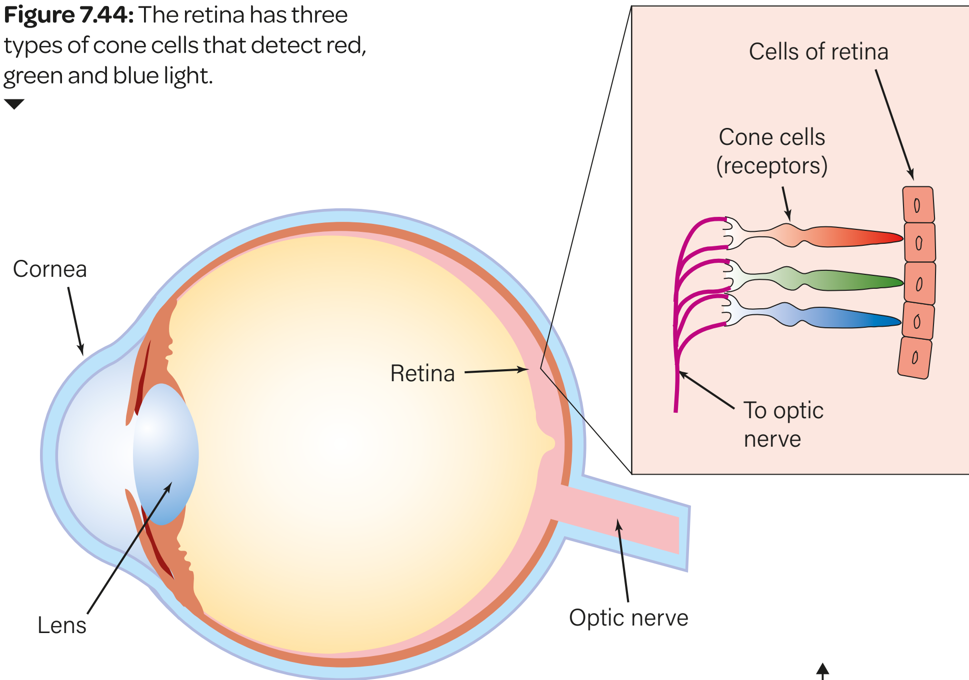


Figure 7.43: Glasses are a lens that helps to focus light onto the retina.

Figure 7.44: The retina has three types of cone cells that detect red, green and blue light.



The retina detects colours in light

The eye sees the colours in visible light. The retina has two types of light receptors:

- **Rods** detect the shades of light and give you black and white vision. Rods enable you to see images in low light – in the dark, you can still see but usually without colour.
- **Cones** detect coloured light. There are three types of cones that detect red, green and blue light. Red, green and blue are the primary colours of light, which combine to make all the other colours of light. For example, red light and green light added together are seen as yellow light. We do not need cones for every colour of light because the brain can create them based on the nerve impulses from the three colour receptors.

Blue light filters absorb blue light

Most electronic screens such as computers and mobile phones produce a significant amount of blue light. Research indicates that excessive exposure to blue light may cause sleep problems, damage to the retina and eye strain. Some research also suggests that glasses that filter blue light can remove 10–25 per cent of blue wavelength light and so help to improve sleep and reduce damage or eye strain. But the scientific evidence is not conclusive about whether the cost of blue filter lenses is worth it and whether they actually protect the eye.

The graph in Figure 7.45 compares the amount of blue light that passes through clear lenses and lenses with a blue filter.

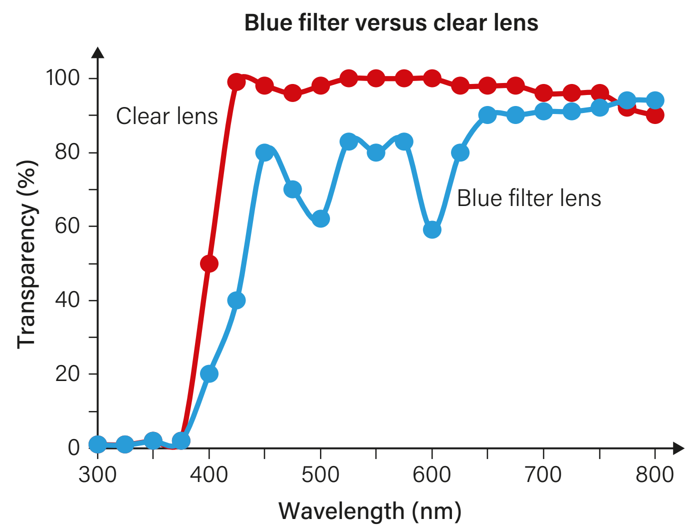


Figure 7.45: The light filtered from a blue filter lens compared to a clear lens. Transparency indicates the percentage of light that passes through the lens.

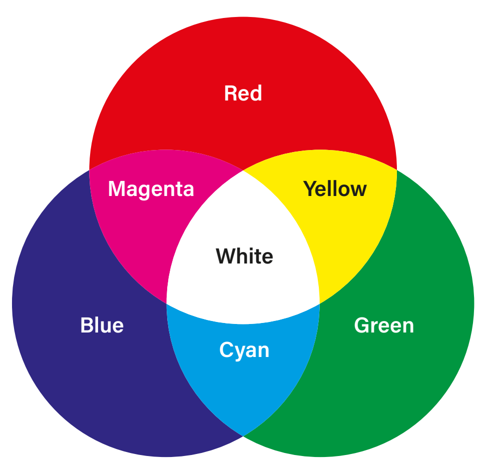


Figure 7.46: By adding green, red and blue together in different amounts, other colours can be created and seen.

We see colours because of reflected light

When we see the colours of an object, such as an apple, it is not because the apple is red but because the object is reflecting red light that enters our eye. That also means the object is absorbing all the other colours that we do not see. In Figure 7.47, we can see that red light is reflected and all other colours are absorbed by the surface.

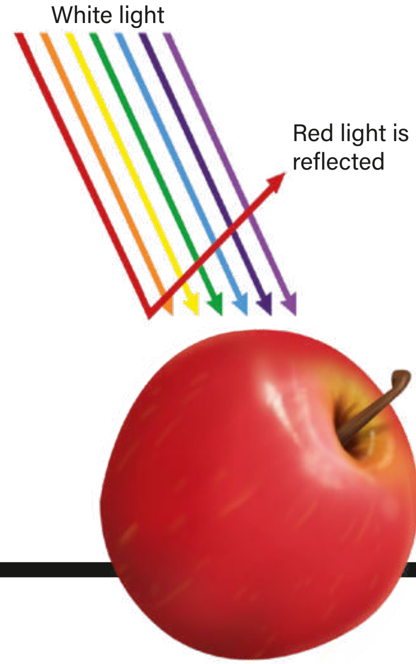


Figure 7.47: The colour of an object is determined by the colours of light that are reflected and those that are not.

Learning Ladder

Waves and motion

1. Identify the part of the eye that:
   - **a** pulls the lens to change its shape.
   - **b** contains receptors to detect light and is like a screen.
   - **c** controls how much light enters the eye.
   - **d** protects the surface of the eye.
   - **e** focuses the light.
   - **f** transfers information from the eye to the brain.
2. Describe how the eye can focus on near and far objects.
3. Explain how lenses are used to correct long- and short-sightedness.
4. Compare rods and cones and outline how they help us to see in different situations.
5. Analyse, using examples, how our understanding of lenses, light and the eye has helped to improve people's lives.

Processing data and information *see page 412*

1. Review Figure 7.44 and use it to answer the following questions.
   - **a** When you look at a red object, red light bounces off the object and other colours are absorbed by the object. Which colour receptor will be activated in the eye when looking at a red object?
   - **b** Describe what happens to the colours in light and which one enters the eye if you look at a blue object.
   - **c** Using your knowledge of light, propose how your eye will detect yellow light. (Hint: Think about what colours of light mix to make yellow.)
2. Copy the following table and use the graph in Figure 7.45 to complete the missing the data.

________ (nm)	Blue filter lens: transparency (%)	Clear lens: transparency (%)
	20	
450		98
600		
650		100

3. In Figure 7.45, the transparency of the blue filter glasses is 60 per cent at 600 nm. Calculate the percentage of light being absorbed by the glass.
4. Refer to Figure 7.45.
   - **a** Estimate the frequency range of blue light being filtered by these glasses.
   - **b** At which wavelength is the most amount of light filtered out by the blue filter lens. At that wavelength, how much is the transparency reduced compared to clear glasses?
5. The scientific evidence is not conclusive about whether blue filter lenses protect the eye. If you were conducting an investigation into the effectiveness of blue light filters, describe some experimental design methods you would use to ensure the accuracy and quality of your data.

In context

Research one of the following issues and create an information card for a medical surgery explaining the issue for patients: colour blindness, contact lenses, corneal transplants, laser eye surgery.

Success criteria

- I can describe the structure of the eye.
- I can describe how the eye responds to light.

7.11 ▸ Stars and the electromagnetic spectrum

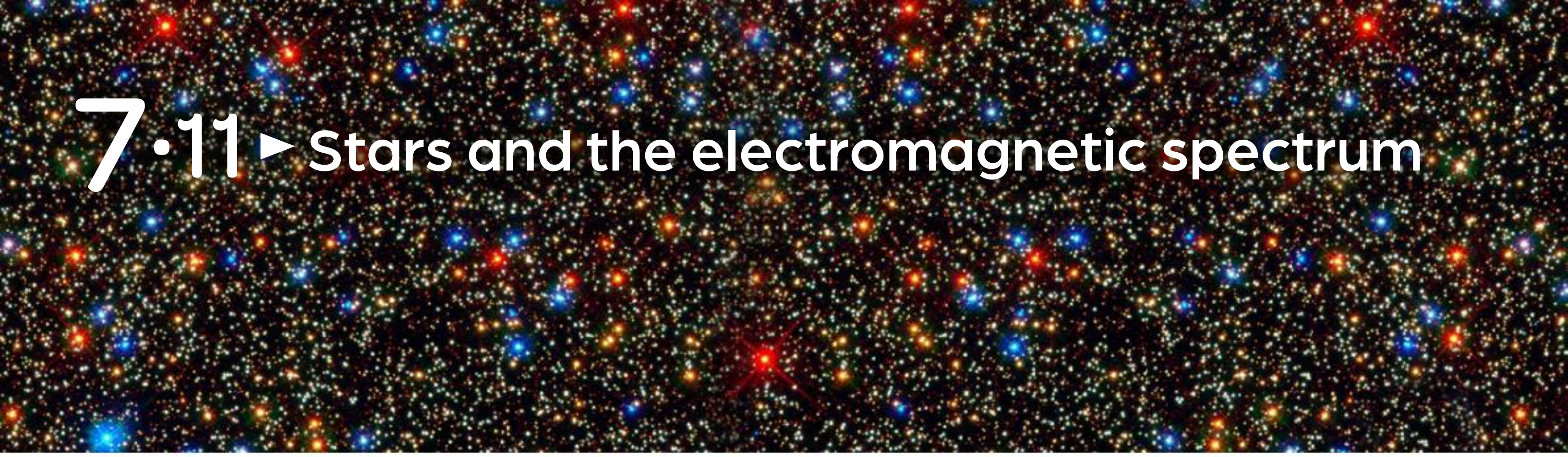


Figure 7.48: The more than 100 000 stars in this image of Omega Centauri are a variety of colours and temperatures.

Learning intention

At the end of this lesson, I will be able to explain how the electromagnetic spectrum is used to learn about stars.

Key terms

ionise: to remove an electron from an atom

neutron star: the small core left over from the collapse of a massive supergiant star when matter is compressed into a small space

star: a burning ball of gas, mostly hydrogen and helium, held together by its own gravity

supernova: the explosion caused when a star collapses and dies

Content group: Light waves

Scientists learn about the universe by using telescopes to look at the different types of light from across the electromagnetic spectrum. Radio telescopes collect radio waves, the Hubble Space Telescope detects visible light, and the Spitzer Space Telescope detects microwaves.

The colours of stars reveal their temperature

Stars release most of their light as visible light. Hotter stars release higher-energy light towards the blue end of the spectrum. Cooler stars release lower-energy light towards the red end of the spectrum. The visible light image of the stars in Omega Centauri in Figure 7.48 was taken by the Hubble Space Telescope. The variety of colours in the stars indicates their different temperatures.

Table 7.8: The colour and temperature of stars

Colour	Temperature (°C)
Blue	30 000–60 000
Blue-white	10 000–30 000
White	7000–10 000
Yellow-white	6000–7000
Yellow	5000–6000
Orange	3500–5000
Red	<3500

Different wavelengths show different stellar objects

Radio waves and microwaves have the lowest energy and allow us to look through clouds of interstellar dust and to see how cold gas moves in space.

We feel infrared light as radiated heat. It is able to pass through the cold dust in the universe, allowing us to study warm gas and dust, and cooler stars. Infrared light can also help us to identify molecules in the atmospheres of planets.

Visible light tells us the temperature of the star and what elements are present.

Ultraviolet light allows us to see the hottest stars that are not easily visible to the eye. It is also used for viewing the hot glow of star nurseries, where new stars are forming.

X-rays are released from the hottest gas clouds containing atoms, when they are heated to millions of degrees. X-rays are released from superheated material that may be spiralling around a black hole or released from a **neutron star** (the small core left over from when a massive supergiant star collapses, compressing the matter into a small space).

Gamma rays have the highest energy and shortest wavelength from across the electromagnetic spectrum. They are released from electrons that have been removed from atoms and accelerated by magnetic fields in exploding stars, or when neutron stars collide, and from supermassive black holes.

The Crab Nebula puts out light across the spectrum

Figure 7.49 shows the Crab Nebula, the expanding remains of an exploding star or **supernova**. Japanese and Chinese astronomers recorded this star exploding nearly 1000 years ago, in 1054.

The images are produced by different telescopes, including the Very Large Array (radio), Spitzer Space Telescope (infrared), Hubble Space Telescope (visible), XMM-Newton (ultraviolet), Chandra X-ray Observatory, and Fermi Gamma-ray Space Telescope.

Each telescope produces different information. For example:

- In visible light, the Hubble Space Telescope tells us which atoms are present in the gas left over from when the star collapsed. Blue in the filaments in the outer part of the nebula represents oxygen, orange is mostly hydrogen, green is sulfur, and red indicates **ionised** oxygen (oxygen atoms with some electrons knocked off).
- The X-ray image shows a white dot near the centre of the nebula. This is a rapidly rotating, highly magnetised neutron star, which is creating shock waves that can be seen as a surrounding ring.

Figure 7.49: The combined image of the Crab Nebula overlays all light from across the electromagnetic spectrum.

Learning Ladder

Waves and motion

1. The colour of stars is related to the energy that is being released. Identify whether blue light or red light has the highest energy.
2. Compare the information about stars that can be obtained from visible light and from gamma rays.
3. Compare the types of objects or matter that can be viewed by an infrared telescope and an X-ray telescope.
4. Estimate and compare the temperatures of the two stars in this image of the constellation Orion.
5. Propose how our understanding of light, stars and telescopes has affected society.

Processing data and information *see page 412*

1. Draw a line representing the electromagnetic spectrum and label each section. Add the name of a telescope that can measure light at each part of the spectrum.
2. Use the information from this and previous sections to construct a table that has three columns: for type of electromagnetic light, for wavelength, and for what it can tell us about stars.
3. **a** Conduct some research to explain what a light-year is, including a definition and the distance light travels in one light-year.
   b If the Crab Nebula is 5.5 light-years across, how many kilometres across is it?
4. A scientist discovers a new star and claims it is yellow with a temperature of 12 450 °C. Refute or support this claim, based on the data in Table 7.8.
5. Research why telescopes are usually funnel shaped. Explain how this shape increases their accuracy.

In context

Explain how the brightness of stars relates to their distance from Earth and their size. How do scientists use this information to work out how far away and how large a star is? Explain the difference between absolute magnitude and apparent magnitude.

Success criteria

- I can give examples of how the electromagnetic spectrum is used to learn about stars.

7.12 ▸ Motion of objects

Learning intention

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

- analyse and calculate the relationships between distance, time, speed, displacement and velocity
- describe motion using diagrams and graphs.

Key terms

average speed: the speed averaged for an entire journey

displacement: the distance an object moves from its starting position

distance: the total length an object travels

instantaneous speed: the speed at a particular time in a journey

speed: the distance an object travels divided by the time taken to travel that distance

velocity: a measure of how quickly displacement changes

Investigation 7.12

Cars and pedestrians, page 585

Content group: Motion

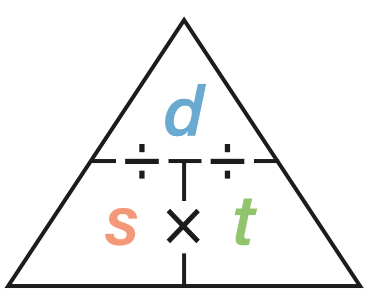


Figure 7.50: A formula triangle for distance (*d*), speed (*s*) and time (*t*)

The world's fastest person is Jamaican sprinter Usain Bolt. Bolt is 1.96 metres tall and holds world records in the 100-metre sprint, 200-metre sprint and 4 × 100-metre relay. You can use the distance of his races and the time he ran them in to calculate his speed. You can also determine his velocity from his displacement and time. How fast do you think Usain Bolt can run? What units are you using to estimate this speed?

Speed is distance divided by time

Distance is how far an object travels. **Speed** is the distance an object travels divided by the time it takes to travel that distance. Speed is often measured in metres per second ($m\ s^{-1}$) or kilometres per hour ($km\ h^{-1}$). The formula for speed is:

$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$

If a car travels 60 kilometres in 1 hour, its speed is 60 $km\ h^{-1}$. From this equation, you can see that if Usain Bolt runs a certain distance in less time than other runners, then he has a higher speed.

A formula triangle allows you to calculate speed

Speed is usually measured in metres per second ($m\ s^{-1}$), distance is usually measured in metres (m) and time is usually measured in seconds (s). To calculate distance or time, you can use a formula triangle (Figure 7.50).

For example, in 2009 Usain Bolt ran 100 metres in a world-record time of 9.58 seconds. Using the distance and time, we can calculate his speed. We know that:

$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$

$$s = \frac{d}{t}$$

$$= \frac{100}{9.58}$$

$$= 10.24\ m\ s^{-1}$$

This is really the average speed, because it would have varied during the run.

Figure 7.51: Distance travelled is calculated using speed and time. How far did Usain Bolt travel in this world-record run in 2016?

If we know speed, we can calculate distance

If one person is jogging and another person is sprinting, and they maintain a constant speed for the entire time, who will travel further in 1 minute? The sprinter is moving at a higher speed , so will cover a greater distance in 1 minute.

If you are riding a bicycle at a constant speed of 4 m s^{-1}, how far would you travel in 3 seconds? From the formula triangle (Figure 7.50), you can see that the formula for distance is $d = t \times s$. So, your distance travelled is 3 s × 4 m s^{-1} = 12 m.

Distance is different from displacement

Distance is how far an object travels, but **displacement** is how far the object is from its initial starting position. If you walk 6 metres north, then 8 metres west, you have travelled a total distance of 6 + 8 = 14 metres. (Try drawing this on a piece of paper.) However, you are only 10 metres from your starting position, so your displacement is 10 metres north-west. Figure 7.52 shows an example.

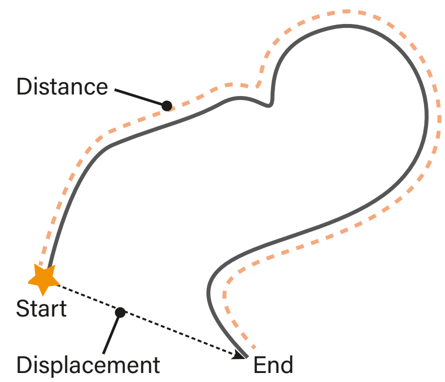


Figure 7.52: Distance and displacement can be very different.

Velocity is a change in speed with direction

Velocity is a measure of the change in displacement in a certain time. In the previous example, if you were walking for 10 seconds, your average speed is distance travelled divided by time taken, so $\frac{10}{14}$ = 1.4 m s^{-1}.

Your average velocity is your displacement divided by the time taken.

The formula for average velocity is:

$$v_{av} = \frac{\Delta s}{\Delta t}$$

where:

Δs is the change in displacement. (Note that '*s*' in this formula is not speed.)

So, your average velocity is:

$v_{av} = \frac{10}{10}$ = 1.0 m s^{-1} north-west

Distance–time graphs represent motion

We can show motion in a distance–time graph, with time on the x-axis and distance on the y-axis. On a distance–time graph:

- When distance increases, the object moves away from the starting position.
- The slope or gradient of the graph tells you the speed – the steeper the slope, the higher the speed, because the object is travelling a greater distance in a certain time.
- If the line is flat, the object is stationary (not travelling any distance). From $s = \frac{d}{t}$, if the distance is zero (not changing), then the speed is zero.
- A straight line tells you the speed is constant (not changing).
- A curved line tells you the speed is changing – either increasing (accelerating) or decreasing (decelerating).
- You can work out the distance travelled from a starting point, and whether the object may return to the start.

From the graph in Figure 7.53, you can work out what each journey shows:

- Journey 1 shows a fast constant speed (steep, straight line going up).
- Journey 2 starts with a slower constant speed (straight line going up), then the person stops (flat line) and returns to their starting position (straight line going down).
- Journey 3 shows a person speeding up (line curving upwards), then slowing down (line curving downwards) and stopping (line flat).

To find the speed at any point on the graph, find the gradient (or slope) at any point in time. For example, in Journey 1, from 0 to 5 seconds, the person travelled 100 metres. From $s = \frac{d}{t}$, the speed is $\frac{100\text{ m}}{5\text{ s}} = 20\text{ m s}^{-1}$.

For Journey 3, the line is bending, so the slope is changing and the speed is not constant. We can still calculate the speed:

1 The **average speed** can be calculated for the entire journey by the total distance over the total time until they stop. Using $s = \frac{d}{t}$, average speed is: $\frac{90\text{ m}}{11\text{ s}} = 8.2\text{ m s}^{-1}$.

2 But we know that the speed changes along the journey. We can calculate the **instantaneous speed** (the speed at any point in time) by calculating the slope of the graph at a particular point. For example, at 50 metres, we can calculate the speed from the slope between 6 and 8 seconds using $s = \frac{d}{t}$, $s = \frac{70-30}{8-6} = \frac{40}{2} = 20\text{ m s}^{-1}$.
This is possible because the slope is constant for this section of the graph.

3 If the slope is curving, we can calculate the speed by drawing a tangent to represent the slope at that point. For example, at 4 seconds into the journey, using the tangent in the graph and $s = \frac{d}{t}$, the instantaneous speed is: $\frac{15}{3} = 5\text{ m s}^{-1}$.

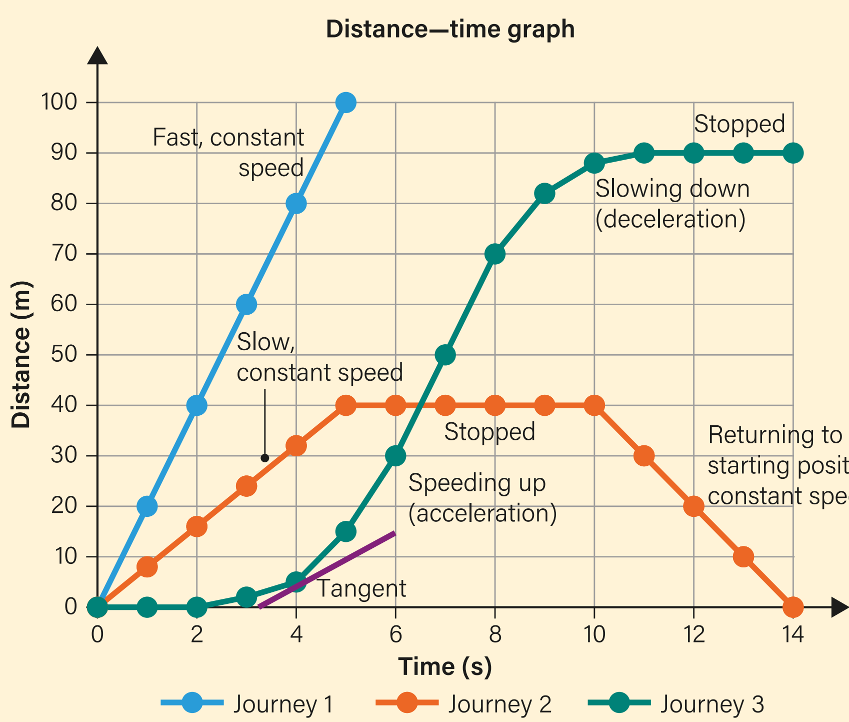


Figure 7.53: A distance–time graph for different journeys

Learning Ladder

Waves and motion

1. Describe how distance, time and speed are related, and identify the units for each.
2. **a** Distinguish between distance and displacement, using an example.
   b A person walks 8 metres north and then 2 metres east. Draw a diagram of their motion showing the distance and displacement.
   c If it took the person in part b 8 seconds to complete the walk, calculate their speed and velocity.
3. Identify and explain an example of how speed and velocity are used in real life.
4. Use the distance–time graph in Figure 7.53 to calculate or identify the:
   a speed for Journey 1 and Journey 2 between 0 and 5 seconds.
   b total distance and displacement travelled for Journey 1.
   c total distance and displacement for Journey 2.
   d instantaneous speed in Journey 3 at 9 seconds.
5. Analyse, using an example, how our understanding of motion, including speed and distance, has contributed to performance in sport.

Conducting investigations

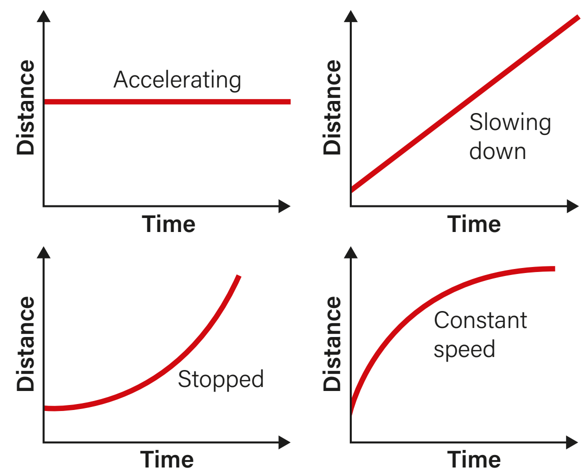
see page 408

1. Data loggers are often used to measure motion. A sensor attached to a ball, trolley or other moving object sends information to a computer or phone. Identify some things you can do to ensure the safe use of data loggers.
2. The following data was collected about a person's travel.
   a Identify the equipment that was needed to collect this information.
   b Construct a distance–time graph for this journey.

Time (s)	Distance (m)
0	0
1	4
2	8
3	12
4	12
5	12
6	12
7	20

Time (s)	Distance (m)
8	30
9	40
10	50
11	80
12	85
13	90
14	90

3. A student sketched and labelled the following graphs from an investigation. Some of the labels are not correctly matched to the graphs. Copy the graphs and label them correctly.



4. A student conducted an investigation at the athletics track by firing a starter's pistol after asking a spectator to time how long it took for them to hear the sound. Sound can travel at 330 m s^{-1}. The spectator heard the pistol 1.8 seconds after it was fired. Calculate how far away they were from the pistol.
5. Research the world-record 100-metres swimming time for males and females and calculate the speed of the swimmers in each case. Remember to acknowledge any sources you use.

In context

Usain Bolt is the world's fastest person. Research his incredible 200-metre world-record race in 2009. Calculate his average speed and velocity during the race, using a diagram of the track as well as calculations for speed and velocity. Hint: You will need to determine his displacement first. Acknowledge your source in an appropriate reference.

Success criteria

- I can analyse and calculate the relationships between distance, time, speed, displacement and velocity.
- I can describe and analyse motion using diagrams and distance–time graphs.

7·13 ► Speed and acceleration

Learning intention

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

- analyse and calculate the relationships between time, speed and acceleration
- describe motion using diagrams and graphs.

Key terms

acceleration: a change in speed over time

deceleration: a decrease in speed over time

Investigation 7.13

Ticker timers, page 587

Content group: Motion

Figure 7.54: A rollercoaster speeds up, changes direction and slows down – all of which are types of acceleration.

Acceleration, that feeling of speeding up or slowing down, is an everyday part of travelling in a car. It can be very exciting, such as when a rollercoaster drops from the highest point and accelerates so fast you feel as though you have left your stomach behind!

Acceleration is a change in speed

Acceleration is a measure of how quickly an object's speed changes. If you drop a ball, it accelerates towards the ground – that is, its speed increases downwards. If you press the accelerator pedal in a car, the car's speed increases in the direction it is moving.

Acceleration is any change in speed or direction over time – speeding up, slowing down or turning.

- If acceleration is in the same direction as an object's motion, the object speeds up.
- If acceleration is in the opposite direction to an object's motion, the object slows down (known as **deceleration**).
- If acceleration is not parallel to the object's motion, the object changes direction.

As long as speed is changing, the object is accelerating. If an object is not moving or is moving at a constant speed, then it is not accelerating. Acceleration (a) is measured in metres per second squared (m s^{-2}) and equals the change in speed divided by the change in time:

$$a = \frac{\Delta v}{\Delta t}$$

Notice the use of the symbol v for speed. This is velocity, which we learnt is speed with direction.

For example, if a car is travelling at 5 m s^{-1} and increases its speed to 25 m s^{-1} over a period of 10 seconds, what is the acceleration?

1 Change in speed = 20 m s^{-1} (final speed – initial speed).

2 Change in time is the 10 seconds it took to speed up.

3 Applying the formula:

$$a = \frac{\Delta v}{\Delta t} = \frac{25-5}{10} = \frac{20}{10} = 2 \text{ m s}^{-2}$$

Speed–time graphs give us more information

We can show speed, acceleration and distance on a speed–time graph, where time is on the *x*-axis and speed is on the *y*-axis.

- When the graph is flat, the speed is constant.
- Acceleration is shown by the gradient (slope) of the line:
  - When the graph slopes upwards with a positive gradient, the object is accelerating.
  - When the graph slopes downwards with a negative gradient, the object is decelerating.
- The area under the graph gives the distance travelled.

We can use this information to analyse the person's journey shown in Figure 7.55:

1 Initially, the person starts with zero speed and accelerates to 10 m s^{-1} over 4 seconds. We can calculate the gradient of the line to find the acceleration:

$$a = \frac{\Delta v}{\Delta t} = \frac{10}{4} = 2.5 \text{ m s}^{-2}$$

2 After accelerating, the line is flat, which shows a constant speed of 10 m s^{-1} between 4 and 8 seconds.

3 From 8 to 10 seconds, the person accelerates again, then there is another period of constant speed from 10 to 12 seconds.

4 Finally, the person decelerates and stops at 16 seconds.

5 We can work out the distance travelled by calculating the area under the graph. For example, between 4 and 6 seconds, the area under the graph is (8 – 4) × (10 – 0) = 4 × 10 = 40 m.

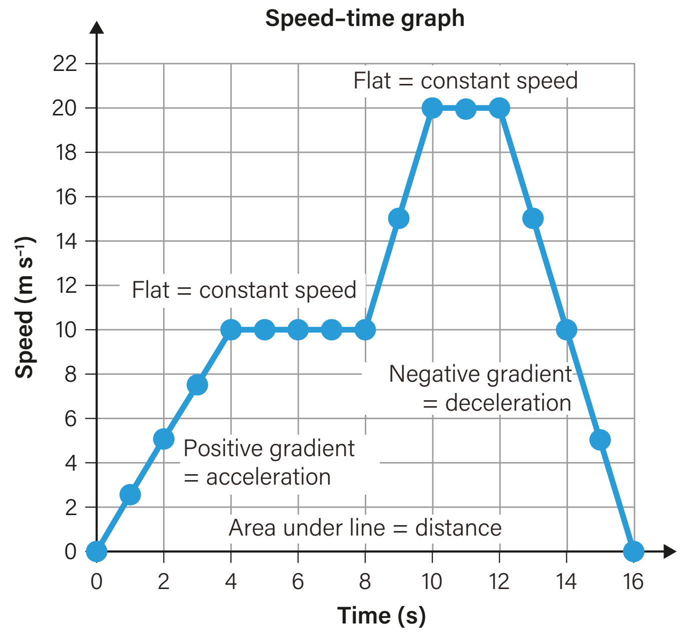


Figure 7.55: A speed–time graph for different stages of a person's journey

Figure 7.56: A car's speedometer indicates its speed during travel. When it accelerates, the needle can be seen to move as the speed changes. Which way will the needle move during acceleration? During deceleration?

Figure 7.57: Different cars accelerate at different rates in a drag race.

Cars accelerate rapidly!

We can compare cars on the basis of how long they take to accelerate from 0 to 100 km h^{-1}. We do this by calculating the average acceleration over a period of time, because the car may accelerate at different rates before it reaches 100 km h^{-1}.

Table 7.9 shows the times for two cars to accelerate from 0 to 100 km h^{-1}. The overall change in speed is 100 – 0 km h^{-1} = 100 km h^{-1}. We need to convert km h^{-1} to m s^{-1}:

$$100 \text{ km h}^{-1} = \frac{100}{3.6} = 27.8 \text{ m s}^{-1}$$

More information about converting between units is available in the Science how-to section on pages 448–49.

Car 1 takes 6.6 seconds to reach 27.8 m s^{-1}. Therefore:

$$\begin{aligned} a &= \frac{\Delta v}{\Delta t} \\ &= \frac{27.8}{6.6} \\ &= 4.2 \text{ m s}^{-1} \end{aligned}$$

Table 7.9: The times for two cars to accelerate from 0 to 100 km h^{-1}

Speed (km h^{-1})	Car 1: Time (s)	Car 2: Time (s)
0	0	0
25	1.6	1.0
50	3.1	2.2
75	5.0	6.1
100	6.6	8.2

Figure 7.58: A ticker timer is a device used to measure speed in scientific investigations. You will use a ticker timer in Investigation 7.13.

Learning Ladder

Waves and motion

1. Identify and describe the three types of acceleration.
2. Describe the difference in acceleration in Figure 7.55 from 0 to 4 seconds, and from 8 to 10 seconds. Justify your answer using your knowledge of the gradient.
3. **a** Calculate the change in speed of a rollercoaster that accelerates to the bottom of a drop at 9.8 m s^{-2} for 4 seconds.
   b If the rollercoaster was already moving at 10 m s^{-1}, what is the final speed at the bottom?
   c Convert the final speed to km h^{-1}.
4. Use the speed–time graph in Figure 7.55 to calculate the:
   a acceleration between 8 and 10 seconds.
   b speed between 10 and 12 seconds.
   c distance travelled between 10 and 12 seconds.
   d acceleration (or deceleration) between 12 and 16 seconds.
   e distance of the entire journey.
5. Propose an everyday use for a speed–time graph. Explain how this demonstrates the impact on society of understanding motion.

Processing data and information see page 412

1. Use the data in Table 7.9 to calculate the average acceleration of Car 2. Compare the two cars and identify which one accelerated fastest to reach the speed of 100 km h^{-1}.
2. **a** Construct a speed–time graph of the data in Table 7.9. You will need a line for each car.
   b Identify which car accelerated fastest to reach the speed of 50 km h^{-1}. Justify your answer.
3. It took Usain Bolt 5.24 seconds to reach his maximum speed of 12.33 m s^{-1} in his world-record 100-metre race. Calculate his acceleration.
4. Jen thinks that Usain could accelerate faster than a car. Compare Usain's acceleration to Car 1 in Table 7.9 and decide if you would support or refute this statement.
5. Rohit tried recording the speed and time of a car accelerating to 100 km h^{-1} in under 10 seconds but had trouble getting accurate results. Propose some methods to improve the accuracy and quality of the data collected.

In context

Investigate the acceleration of different machines, including rockets, aeroplanes, cars, motorbikes and bicycles. Collect data and construct a table to compare the acceleration of each machine you identify.

Success criteria

- I can analyse and calculate the relationships between time, speed and acceleration.
- I can describe and analyse motion using speed–time graphs.

7.14 ▶ Newton's laws of motion

Learning intention

At the end of this lesson, I will be able to explain Newton's laws of motion and their applications.

Key terms

balanced forces: forces acting on an object are equal and cancel out, so that motion remains the same

force: a push, pull or twist, measured in newtons (N)

inertia: a property of matter that causes it to resist change in speed or direction (to remain at rest or in a state of uniform motion)

mass: the amount of matter in an object, measured in grams (g) or kilograms (kg)

unbalanced forces: forces acting on an object are different in size and do not cancel out but cause a change in motion

Investigation 7.14A
Car crashes and inertia, page 589

Investigation 7.14B
Balloon rockets, page 591

Content group: Motion

Isaac Newton was an English scientist who lived in the 1600s. He is so well regarded that the unit of force is named after him. Among his many achievements are his three laws of motion, which describe how objects move in relation to the **forces** applied to them.

Newton's first law: an object stays at rest or at the same speed unless an unbalanced force acts on it

Newton's first law states that an object at rest remains at rest, and an object in motion remains in motion at constant speed and in a straight line, unless acted on by an unbalanced force that changes its motion.

An **unbalanced force** is a force that causes a change in motion. This means that a stationary object will remain stationary until a force such as a push or pull starts it moving. It also means that a moving object will keep moving unless a force acts on it, such as pushing the object to change its direction or pushing or pulling it to slow it down or speed it up.

If a car is rolling on the road, it will not keep rolling forever because there is an unbalanced force acting on the car – friction. The car will experience friction from the road and from the air. The friction converts the kinetic energy to heat and sound, and the car slows and stops.

A car travelling at a constant speed also experiences friction. In this case, the friction from the road is equal to the thrust from the engine – the forces are equal in both directions and **balanced** (Figure 7.59a).

If the car accelerates, then thrust is larger than friction and the unbalanced force causes the car to accelerate (Figure 7.59b).

If the car brakes, friction is larger than thrust and the unbalanced force causes the car to slow down (Figure 7.59c).

The property of an object that keeps it doing what it is doing – whether that is to stay in motion or at rest – is **inertia**. Inertia is related to mass. An object with more inertia (more mass) requires more force to start or stop it. For example, a truck has more inertia than a car, so the truck is harder to stop because it has more mass.

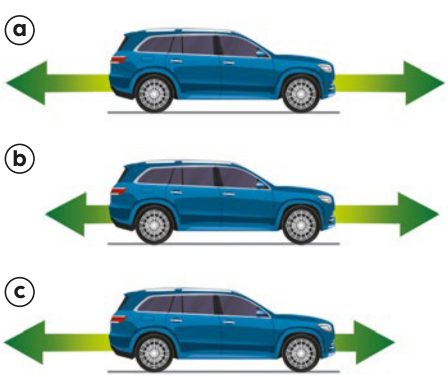


Figure 7.59: Newton's first law: unbalanced and balanced forces on a car. Can you tell which car is accelerating?

Newton's second law: force = mass × acceleration

Newton's second law states that the acceleration of an object is proportional to the force applied and inversely proportional to the **mass** of the object.

This law is represented by the equation $F = m \times a$, where F is force (N), m is mass (kg) and a is acceleration (m s^{-2}).

The heavier an object is, the more force is required to accelerate it. If the force applied to an object is constant (the same), and the mass is doubled, then the acceleration halves. If mass is halved, then acceleration is doubled.

We will learn more about Newton's second law in Section 7.15.

Newton's third law: for every action, there is an equal and opposite reaction

Newton's third law tells us that every force has an equal and opposite reaction force.

This means that if object 1 exerts a force on object 2, then object 2 exerts the same-sized force on object 1, but in the opposite direction. For example, if you push on the wall with both hands, you can feel the wall pushing back on your hands as pressure – the harder you press (the more force you apply), the more you can feel the wall pushing back with equal force.

Riding a skateboard involves pushing backwards to move the skateboard forwards. These equal and opposite forces are known as action–reaction pairs.

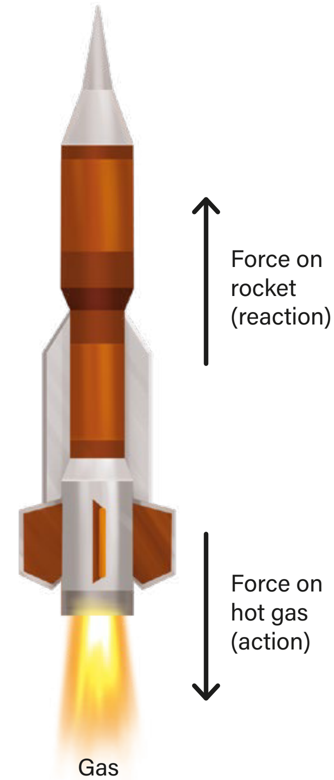


Figure 7.60: Newton's third law: action and reaction forces in a rocket

Learning Ladder

Waves and motion

1. Define 'inertia' and outline how it applies to large and small moving objects.
2. Draw a diagram of a real-life example to compare balanced and unbalanced forces on an object.
3. Using Newton's third law, explain how a rocket works.
4. State the formula for Newton's second law and explain what each value in the formula stands for.
5. Provide an example of how Newton's laws and our understanding of motion have had an impact on society.

Conducting investigations

see page 408

1. Propose some safety measures when undertaking an investigation using rockets to explore Newton's laws.
2. Load a toy trolley with some objects to increase the mass. Perform the following investigation on a smooth surface, pushing the trolley from a start line and measuring the distance it travels.
   1 Push the trolley gently, and then harder.
   2 Add some objects to the trolley to increase the mass. Push it gently, and then harder.
   3 Record your observations in each case and answer these questions.
   a Describe what you are doing in terms of force when you push harder.
   b Describe how changing the force and mass changed the distance and acceleration.
   c Identify which of Newton's laws this investigation demonstrates. Justify your answer.
3. For the investigation in Question 2, imagine you need to measure the acceleration with a data logger, to more accurately compare the mass and force on each trolley. Construct a data table for your results and ensure you correctly add any required units.
4. James stood on a skateboard, holding a large heavy medicine ball and threw the ball to Jenny.
   a Describe what observations you would expect to see when James throws the ball.
   b Identify which of Newton's laws this investigation demonstrates. Justify your answer.
5. Research Sir Isaac Newton and explain another of his important discoveries. Remember to reference your sources.

In context

Undertake research to explain an example of where balanced and unbalanced forces are important in sport.

Success criteria

- I can explain Newton's laws of motion and their applications.

7.15 ▸ Force, mass and acceleration

Learning intention

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

- analyse the relationships between force, mass and acceleration
- describe motion using diagrams and graphs
- apply Newton's laws.

Key terms

inversely proportional: as one quantity increases, the other decreases

proportional: as one quantity increases, so does the other

weight: a force acting downwards on a mass due to gravity

Investigation 7.15

Acceleration and mass, page 592

Content group: Motion

Figure 7.61: It requires less force to accelerate a skateboard than to accelerate a heavy car.

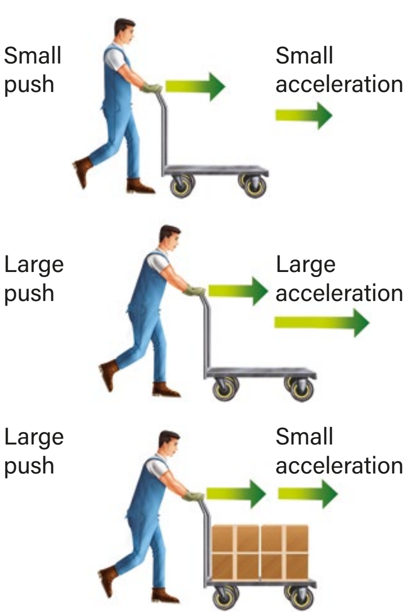


Figure 7.62: Newton's second law: the heavier an object is, the more force is required to accelerate it.

It requires a lot of force to get a car moving. But you can get a skateboard moving with just your foot. The difference is mass: a car is much heavier than a skateboard and so requires a much greater force to make it accelerate.

Acceleration depends on mass and the size of the force being applied

If you use your foot to propel yourself on a skateboard, the force of your foot pushing backwards against the ground causes your acceleration forwards. If someone is standing on the skateboard with you, the total mass increases, so you need to apply more force.

The relationship between force, mass and acceleration is summed up by Newton's second law, which says that the acceleration of an object is **proportional** to the force applied, and **inversely proportional** to the mass of the object:

$$F = m \times a \quad \text{or} \quad a = \frac{F}{m}$$

As shown in Figure 7.62, if you increase the force on an object of fixed mass, the acceleration increases. If you use the same force but increase the mass, the acceleration decreases.

We can use $F = ma$ to calculate force

You can calculate the force required to accelerate an object from the formula $F = m \times a$. To calculate mass or acceleration, you can use the formula triangle in Figure 7.63.

Table 7.10 shows the force required to accelerate three trolleys. Trolleys 1 and 2 are the same mass, but Trolley 2 has more force applied, so it has a higher acceleration. Trolleys 2 and 3 have the same force applied, but Trolley 3 is heavier, so it has a lower acceleration.

Table 7.10: Calculation of forces to accelerate trolleys

Trolley	Mass (kg)	Force (N)	Acceleration ($m\ s^{-2}$)
1	20	50	2.5
2	20	500	25
3	25	500	20

Weight is a measure of force

You learnt in Stage 4 that mass and weight are not the same. Mass is measured in grams or kilograms and is a measure of the amount of matter in an object, whereas **weight** is the force acting on your body's mass due to gravity.

To calculate the weight force, we can rewrite $F = ma$ as $W = mg$, where W is weight (N) and g is the acceleration due to gravity ($9.8\ m\ s^{-2}$ on Earth). So, if your mass is 68 kg, your weight on Earth is: $W = 68 \times 9.8 = 666.4$ N. Heavier objects with more mass have larger weights.

The acceleration due to gravity on Earth is always $9.8\ m\ s^{-2}$, so two objects that are dropped always accelerate at the same rate and hit the ground at the same time.

Gravity changes as we move away from Earth's surface. Gravity on the Moon and other planets is also different from gravity on Earth. A person would weigh less on the Moon ($g = 1.6\ m\ s^{-2}$) and more on Jupiter ($g = 24.8\ m\ s^{-2}$).

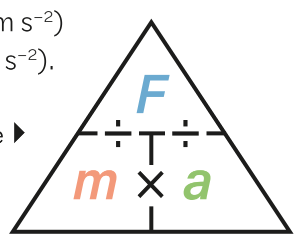


Figure 7.63: A formula triangle for force (F), mass (m) and acceleration (a)

Learning Ladder

Waves and motion

1. Describe the relationship between force, acceleration and mass, and identify the units for each quantity.
2. Describe how to calculate force and weight, and include the formulas for each.
3. Explain how our understanding of force, mass and acceleration is useful in manufacturing trucks of different sizes.
4. Compare the forces needed to accelerate a 22 kg cheetah at $15\ m\ s^{-2}$ and a 15 kg gazelle at $10\ m\ s^{-2}$.
5. Analyse the effect of an object's mass on its weight, using a named example.

Conducting investigations

see page 408

You are about to complete an investigation, dropping objects of different masses from a balcony and recording the time taken for them to hit the ground.

1. Construct a risk assessment for this activity.
2. Collect some objects (e.g. balls) of different mass that will not break when dropped. Make sure some of the balls are much heavier than others.
   - **a** Use an electronic balance to measure the mass of each object.
   - **b** Drop each item from a balcony three times and record the time taken for each to hit the ground.
   - **c** Drop two objects of different mass at exactly the same time. Observe when they hit the ground.
3. Identify any sources of error in your investigation.
4. **a** Assess how accurate you think your data is for this investigation. Justify your answer.
   - **b** Use your findings from your investigation to make a conclusion.
5. Conduct research to find the results of a similar experiment (remember to record any sources used). Compare those results to your results and explain whether they support your own findings.

In context

Construct a table showing how your weight would change as you move further away from Earth's surface. You will need to research the gravity at different distances from Earth's surface.

Success criteria

- I can analyse the relationships between force, mass and acceleration.
- I can apply Newton's laws of motion in everyday situations, including calculating weight of objects.

7·16 ▸ Net force

Learning intention

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

- use vectors to determine the net force on an object
- apply Newton's laws.

Key terms

magnitude: the size of a measurement

net force: the sum of all forces acting on an object

normal force: the force of the ground pushing up in opposition to gravity

vector: a quantity that has direction and magnitude

Content group: Motion

In a game of tug of war, two teams pull on each end of a rope. They are applying opposing forces. The team that applies the largest force wins by pulling the other team towards them. If we know the force in each direction, we can work out the overall force and who will win the tug of war.

Vectors have a size and direction

We learnt that displacement has a direction as well as a **magnitude** (size); for example, 6 m s^{-1} east. Quantities that have both a direction and a magnitude are called **vector** quantities. Other vector quantities are acceleration and force, because they act in a direction.

In Figure 7.64, we can see two vectors: 2200 N to the left and 2800 N to the right.

Net force is the sum of all forces on an object

The **net force** is all the forces acting on an object added together.

In Figure 7.65, people are shown pushing a trolley. The applied force is represented as a vector by an arrow to show the direction and size. In the first image, a person is pushing the trolley with a force of 500 N to the right. The total or net force is 500 N to the right.

In the second image, two people are pushing in the same direction – to the right. One person pushes with 500 N of force, and the second with 200 N of force. The net force is now 500 + 200 = 700 N to the right.

Figure 7.64: Which team will win in this tug of war, and in what direction will the rope move? ▼

In the third image, one person pushes with 500 N to the right, and the second with 200 N to the left. The forces partially cancel out. To find the net force, we calculate 500 – 200 = 300 N to the right.

Forces can also act up and down. The force due to gravity, or weight, acts downwards in the direction of gravity (Figure 7.66). We know from Newton's third law of equal and opposite forces that the ground pushes back up with an equal force. The force of the ground pushing up is known as the **normal force**.

Figure 7.67 shows vectors for a person standing still. The net force equals zero (668 – 668 = 0 N). If the person were to jump, they would need to have a net force upwards to move in that direction. In the second diagram, we can see that the vectors will partially cancel, with the net force calculated as 800 – 668 = 132 N upwards, enabling the person to jump.

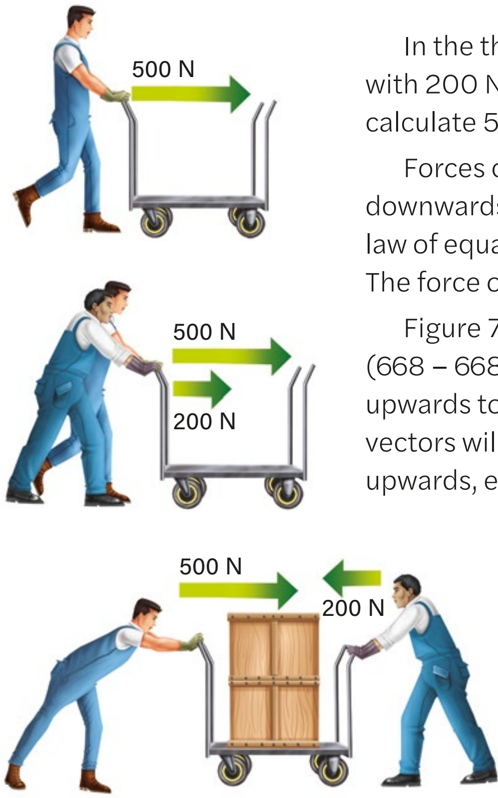


Figure 7.65: Net force is the sum of the different forces acting on an object.

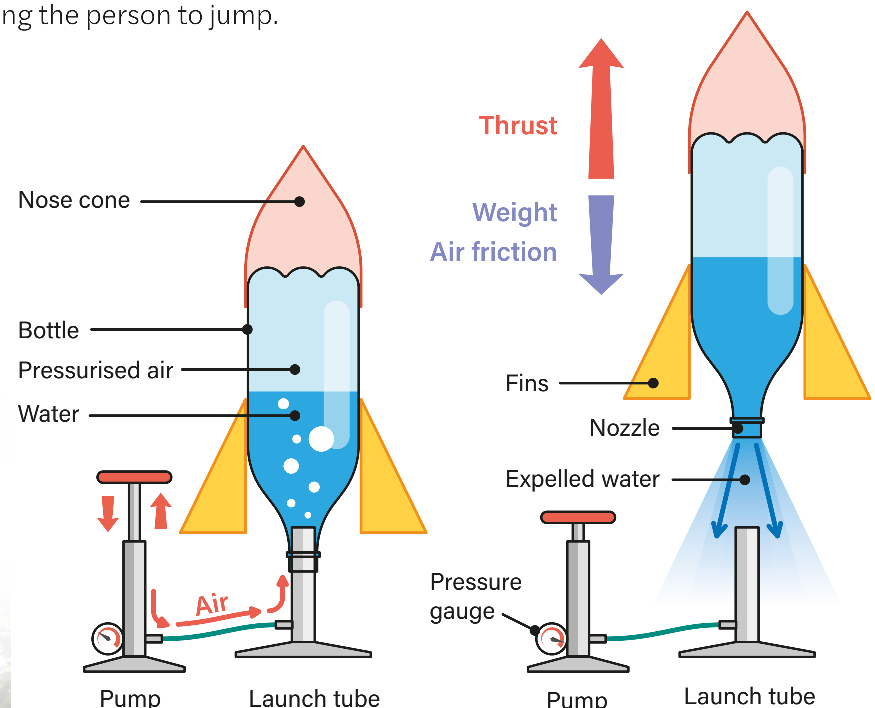


Figure 7.66: For a water rocket to launch, the net force upwards (thrust) must be higher than the force of gravity (weight) and friction downwards.

Figure 7.67: To jump, the net force must be upwards.

We can calculate the net force on a rocket

Can you imagine the force required to launch a rocket that has a mass of 1.5 million kg? The net force must be upwards, with the thrust being larger than the weight. That is, the net force = thrust – weight.

1. We can calculate the weight using $W = mg$:
   $W = 1\,500\,000 \text{ kg} \times 9.8 \text{ m s}^{-2}$
   $= 14\,700\,000$ (i.e. 14.7 million) N downwards.
2. If the thrust is 60.5 million N upwards, we can calculate the net force as follows:
   Net force = thrust – weight, or
   60 500 000 N – 14 700 000 N =
   45 800 000 (i.e. 45.8 million) N upwards,
   and the rocket takes off!

Forces on an object can act in many directions

Consider the forces acting on a cyclist. The driving force of their feet on the pedals is propelling them forward. Gravity is also acting on them, providing a weight force. Friction between the tyres and the road, as well as air resistance, opposes their motion. Finally, there is the force from the road pushing the bicycle upwards – the normal force.

To calculate the net force acting on the cyclist, add together all the forces acting in the same direction and subtract the forces acting in the opposite direction.

- In the vertical direction, the weight force (600 N) is acting in the opposite direction to the normal force (600 N), so subtract these: 600 N – 600 N = 0 N. In the vertical direction, the sum of the forces is zero, so you can ignore them.
- Air resistance (50 N) and friction (70 N) act in the same direction, so add these together. The total force acting to the right is 50 N + 70 N = 120 N.
- The pedal force (220 N) is to the left, which is the opposite direction to the friction and air resistance, so subtract them.
- Therefore, the net force is 220 N – 120 N = 100 N to the left.

Figure 7.68: The large mass of the rocket means it requires a huge upwards net force to increase its speed.

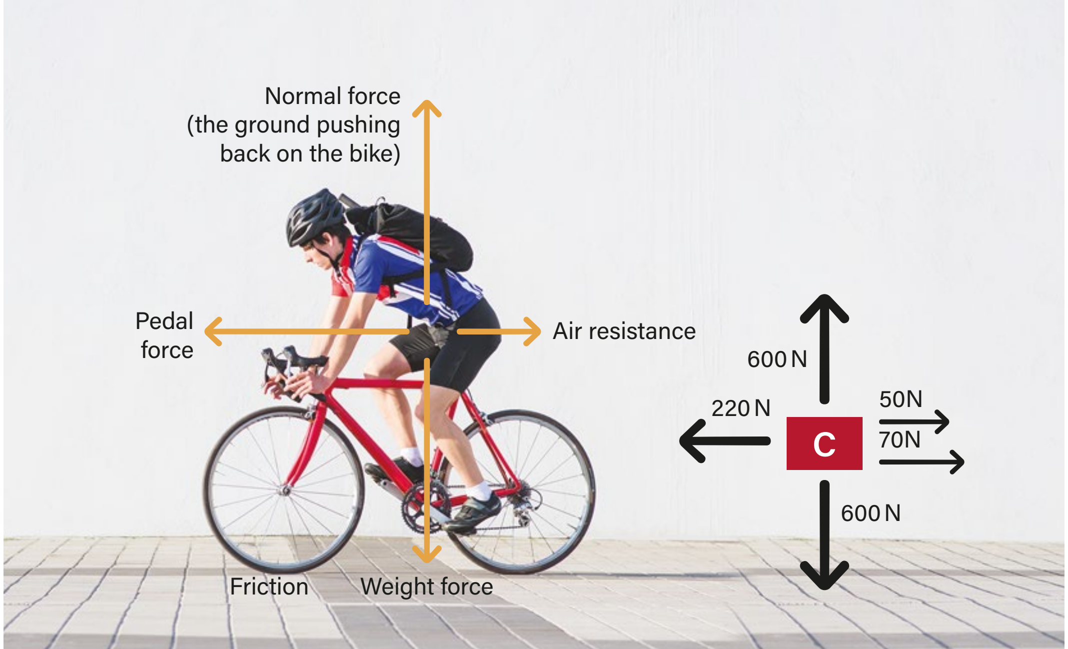
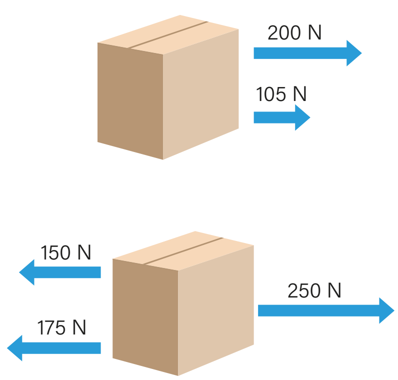


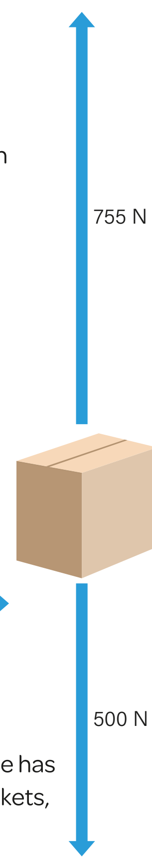
Figure 7.69: All the forces on a cyclist can be added to calculate the net force.

Learning Ladder

Waves and motion

1. Explain what a vector is, using an example.
2. Using an example, describe what net force means in relation to moving objects.
3. Use an example to explain how vectors can demonstrate Newton's laws.
4. Calculate the net force on each of the following boxes.





5. Analyse how our understanding of net force has allowed us to design machines such as rockets, or cranes that lift and move objects.

Processing data and information

see page 412

1. Using the data for the rocket launch, draw a diagram of a rocket. Add vectors for each force and an overall vector for the net force.
2. Draw vector diagrams for the following and calculate the net force on the objects.
   - **a** A person on a skateboard pushes with a force to the right of 100 N; friction to the left is 75 N.
   - **b** A person jumping on a trampoline lands on the mat. Their downward motion exerts a force of 400 N. Their weight force downwards due to gravity is 700 N. The trampoline mat pushes up with an equal and opposite force.
3. Calculate the net force from the tug of war shown in Figure 7.64 and identify which team will win.
4. Review the cyclist in Figure 7.69.
   - **a** As the cyclist is riding, the wind becomes stronger and air resistance increases to 120 N. Describe the change to the net force and what happens to the rider.
   - **b** Air resistance continues at 120 N, and the ground becomes rough, increasing friction to 100 N. Describe what happens to the rider.
   - **c** The wind slows and the road returns to normal. The rider picks up a heavy load in their backpack. Describe the effect on the friction force. How can the rider now maintain the same speed?
5. The Tour de France is a major cycling event, and cyclists look for every advantage to win. Understanding the forces on a cyclist, including air resistance, to reduce their energy use and increase their speed is very important. Propose some methods for how a team could collect data about the forces on the cyclist in order to increase speed.

In context

Investigate the net force on a skydiver during different stages of a jump and produce a report outlining your findings. Use vectors to illustrate the forces at each stage of their fall.

Success criteria

- I can use vectors to determine the net force on an object.
- I can provide examples of how Newton's laws can be applied.

7.17 ▸ Waves and motion in context

Learning intention

At the end of this lesson, I will be able to structure an argument to analyse how waves and motion have changed society.

Key terms

claim: what you want to tell other people about and get them to believe

scientific argument: an idea supported by facts and evidence to persuade other people

Content group: Waves and motion in context

This focus area has outlined some of the many applications of waves and motion in our daily lives and technology. Think of rockets putting satellites into space, and of those satellites providing GPS or high-speed internet. Our wi-fi and mobile phones connect to the internet, enabling our communications, and so on. In this section, you will select an example of the ways in which waves and motion have changed society and construct an argument to explain how and why.

A scientific argument uses reasoning and evidence

A **scientific argument** is when you present an idea supported by facts and evidence. The basic structure for a scientific argument consists of three parts, as shown in Figure 7.70.

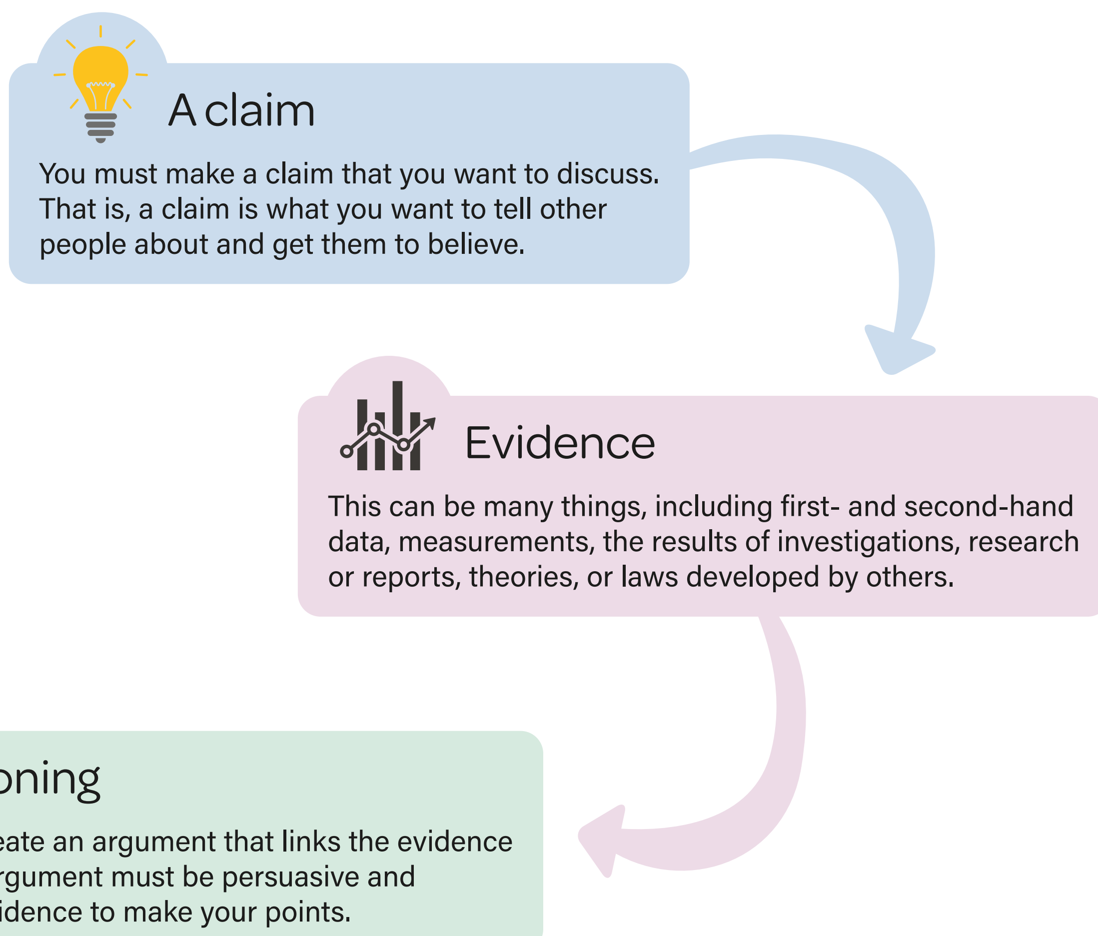


Figure 7.70: Scientific research produces evidence that can support a claim.

Figure 7.71: Seatbelts and car safety have become more effective because of our understanding of motion.

A good claim has a cause and effect

A **claim** should be clear so that people know what you are trying to convince them about. Ideally, a claim includes a cause and an effect. It only has to be a short statement. Here are some examples of well-structured claims:

1. The invention of satellites has changed society; by using electromagnetic waves, we can navigate around the world more effectively.
2. Our understanding of Newton's laws of motion and of inertia has led to the development of seatbelts in cars, which have saved many lives and reduced the numbers of injuries from car accidents.

Notice how each claim has a cause and the related effect. This makes it clear what you are arguing and why it is important (what the impact on society is).

Evidence supports your claim

Next, you need to identify and collect evidence so that you can analyse your claim. Strong evidence supports a claim and makes it more persuasive. Strong evidence:

- is accurate and scientifically correct
- is reliable – is based on data or well-designed scientific investigations, or on sources and reports that are based on good evidence and not opinion or 'fake' science
- uses facts and figures, data, analysis and other evidence, including data in tables or graphs, to support your claim.

Consider the following evidence-based statements:

1. 'Mobile phones have affected society a lot because everyone I know has one, and we use social media all the time.'
2. 'In 2024, only 3.6 per cent of Australians between 16 and 64 years of age don't have a smartphone, demonstrating that mobile phones are widely used. A report published in 2024 shows that, on average, people use smartphones for 3 hours a day for play, for work and to interact with friends and family.'

Statement 1 is an opinion and has no evidence or data to back up the claim. Statement 2 includes data from a report, including the year of the data and facts and figures from that source, making a stronger argument. You would need to list any sources used to create your argument. When selecting evidence, ask yourself:

- Where is the data or evidence from and who collected it?
- Is the source of that data or evidence reliable and trustworthy?
- Do I have more than one source of data and evidence, to make a stronger case?
- Does the evidence support or refute my argument?

Reasoning completes your argument

Now that you have your evidence, you can create a strong argument for your claim by linking the evidence to your claim. Your reasoning explains why the evidence links to your claim and provides justification for it.

Your reasoning:

- should use clear scientific language and facts where possible
- explains the big idea that connects the evidence to the claim.

Consider the following two examples of reasoning:

1 'It's better to have mobile phones because they are useful, and our understanding of electromagnetic waves made this possible. They make life easier and things faster and keep us connected more often than in the past.'

2 'The science shows that there is very high usage of mobile phones, with more than 90 per cent of Australians having one. Phones have many uses and have affected society in many ways, including making us more connected. (People use their phones for more than 3 hours per day on average.) Mobile phones provide more access to information and automate processes such as banking and job applications, which saves us time. It has been calculated that mobile phones save Australians 10 hours per week compared to when they did not exist. This has changed society, how we find and use information, and how we interact and communicate. This change in society has occurred because of our in-depth understanding of electromagnetic waves, and how we can use them to transmit information using radio frequencies and microwaves.'

Statement 1 is more of an opinion and has limited facts and scientific language to back up the claim. Statement 2 uses more scientific language, summarises supporting facts, and relates back to and clearly explains the claim that electromagnetic waves have changed society.

Check if your argument is strong

After you have created your argument, you should test how good it is. This can be done in a number of ways.

- Present it to friend and see if they challenge anything or find gaps in your evidence or argument.
- Try to think of arguments or evidence against your claim. If you find any arguments that weaken your claim or could be used to argue against you, find more evidence with which to oppose them.

Make sure you have listed all your sources and references to prove that your evidence is reliable.

Figure 7.72: Mobile phones are a good example of how our understanding of electromagnetic waves has changed society.

Figure 7.73: Presenting your argument will include using evidence to persuade others. You may want to practise your presentation on someone before presenting to the class.

Create your own argument!

Use this simple model to create an argument of your own to analyse how waves and/or motion have changed society.

1. Brainstorm ways that our knowledge of waves and/or motion has changed society. (Your teacher may lead this as a class activity.)
2. Select a topic for your argument.
3. Develop your claim.
4. Research and collate your evidence, draft your evidence statements and record your sources.
5. Develop your reasoning.
6. Draft and redraft your argument until it flows well and makes sense – connecting your claim, evidence and reasoning into a logical flow.
7. Check if your argument is strong and strengthen any weaknesses.
8. Present your argument in a format of your choice. (Your teacher may ask you to present your argument to the class.)

Learning Ladder

Waves and motion

1. Identify the three parts of an argument.
2. Describe what a 'claim' is.
3. Look back through the focus area and identify an application of waves and motion that you think has changed society. Explain why you chose this example.
4. Give an example of a piece of evidence you could use that includes data or mathematical analysis to demonstrate that waves and motion have changed society.
5. Find evidence that supports why you think the example you chose in Question 3 has changed society.

Processing data and information *see page 412*

1. Identify and explain what you think is the most important aspect of a strong argument.
2. Summarise the three parts of a good argument in a visual format of your choice.
3. If using data to support a claim, explain the importance of correctly stating SI units and values in relation to making your argument.
4. Look back through the focus area and identify some data that could be used as evidence to support an argument for waves or motion changing society.
5. When looking for evidence online, propose ways that you can check that it is reliable and trustworthy.

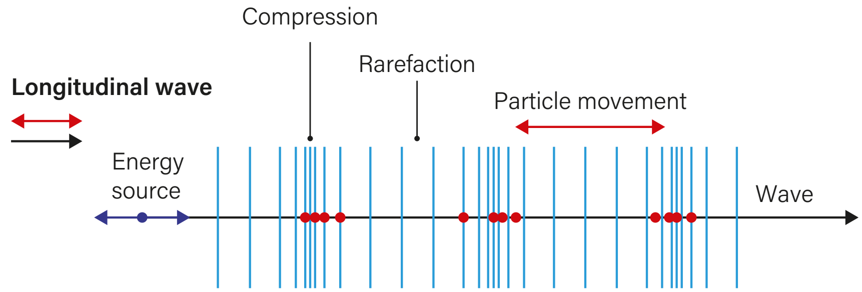
Success criteria

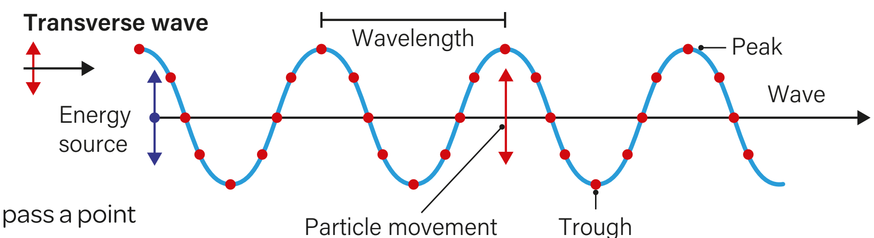
- I can structure an argument using scientific evidence and facts and language.
- I can analyse how waves and motion have changed society.

► Waves and motion summary

Common properties of waves

- A wave is the transfer of energy from one place to another.
- Mechanical waves (e.g. sound) require matter (or a medium) to move through. Energy is transferred, but not matter.
- Light waves (a type of electromagnetic wave) do not need a medium.
- Longitudinal wave: particles of the medium vibrate in the direction of energy transfer.
- Transverse wave: vibrates at right angles to the direction of motion.



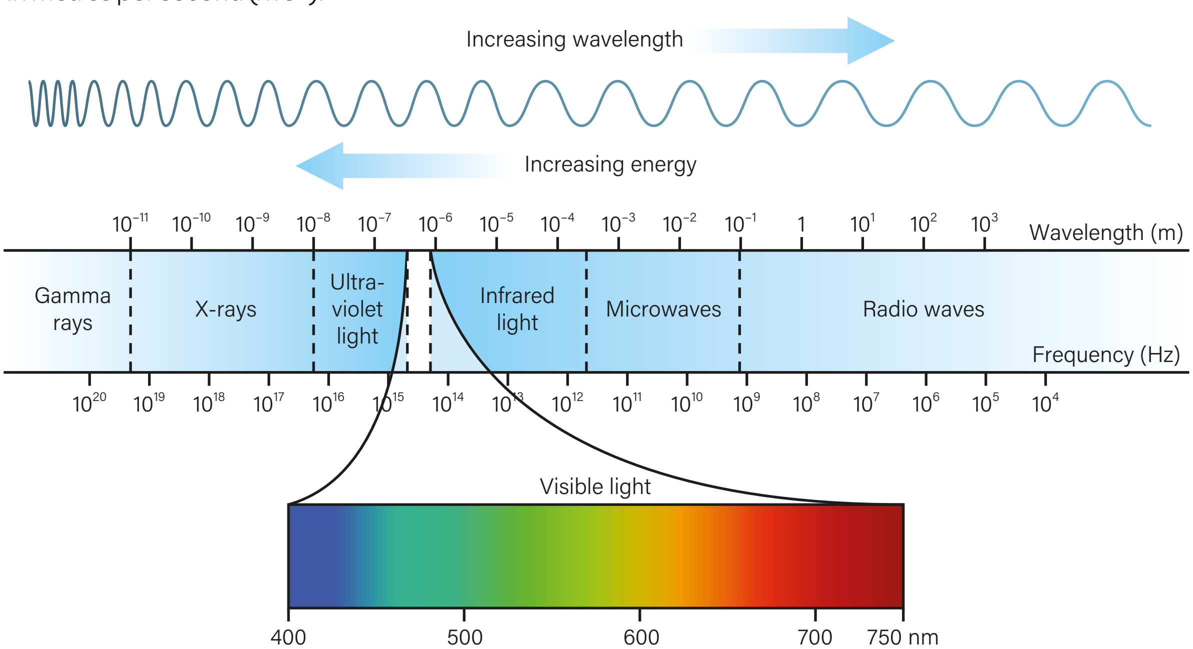


- Properties of waves:
  - **Frequency** (f): number of waves that pass a point each second; hertz (Hz). High frequency = higher energy.
  - **Wavelength** (λ): distance from the peak of one wave to the peak of the next wave; metres (m), centimetres (cm).
  - **Amplitude**: distance from the peak (top) or trough (bottom) of a wave to the middle. High amplitude = higher energy.
  - **Speed** (v): sometimes called velocity; measured in metres per second (m s^{-1}).

- The formula for the relationship between frequency, speed and wavelength is:

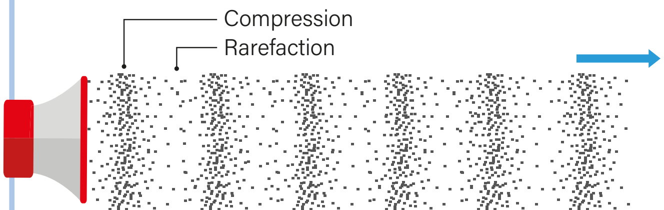
$$\lambda = \frac{v}{f}$$

- Electromagnetic waves are transverse waves made up of magnetic fields and electric fields travelling together.
- Electromagnetic waves travel at 300 000 km s^{-1} (the speed of light).



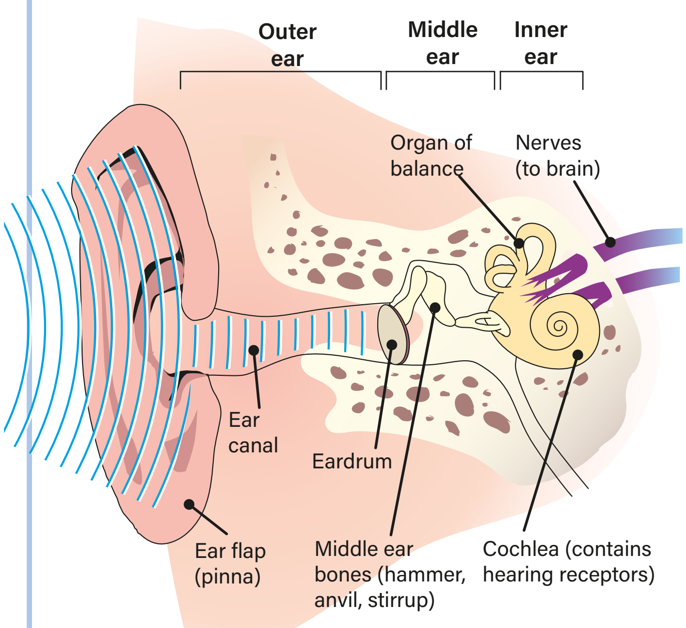
Sound waves

- Sound waves are made up of rarefactions and compressions.

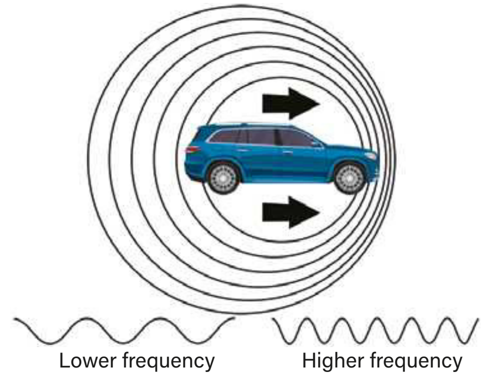


Longitudinal wave

- The pitch of a sound is the frequency; hertz (Hz).
- The volume is related to the amplitude; decibels (dB).
- The Doppler effect is the change in frequency as an object moves towards or away from an observer.
- The ear detects vibrations in the air. Humans can detect frequencies from about 20 Hz to 20 kHz (20 000 Hz).
- Loud sounds over 90 dB can damage the ear.



Moving sound source

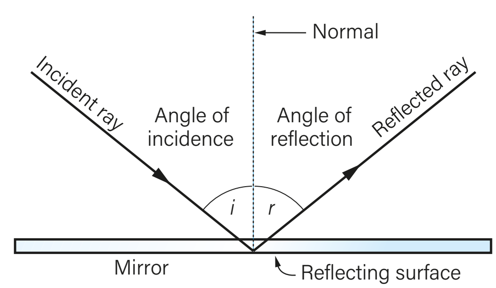


- There is a lower frequency (lower pitch) and longer wavelength behind a car, and a higher frequency (higher pitch) and shorter wavelength in front.
- Musical instruments generate sounds by vibrating. The sound is influenced by the type of material used to construct the instrument.
- Aboriginal and Torres Strait Islander Peoples use instruments for both social and cultural reasons.
- Medical uses of sound include stethoscopes, and instruments like ultrasound used for imaging inside the body. Doppler flow meters can measure blood flow.

Light waves

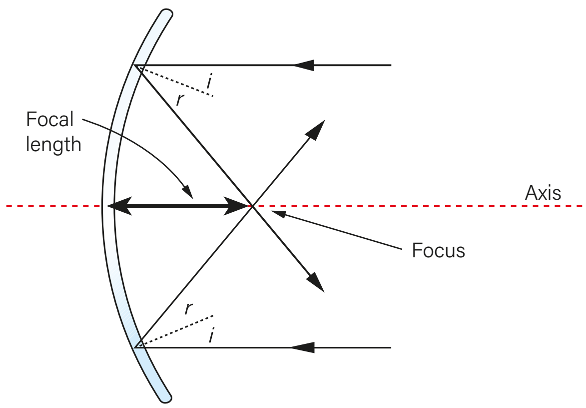
- Materials that allow light to pass through are known as transparent (e.g. glass). Translucent materials allow some light to pass through (e.g. frosted glass). Opaque materials do not allow any light to pass through and either reflect or absorb it (e.g. aluminium foil).
- Light is reflected off a shiny surface such as a mirror.

Angle of incidence = angle of reflection

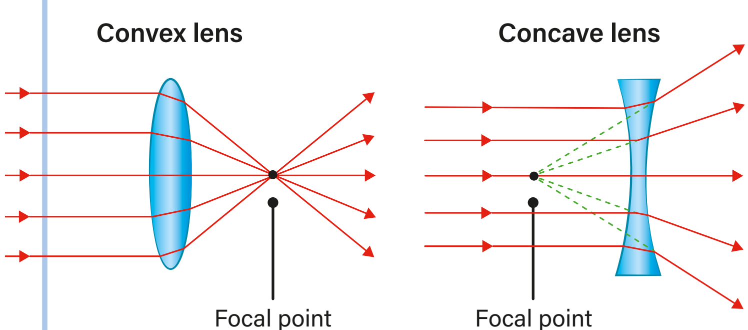


- A concave mirror reflects light rays to a focus. A convex mirror reflects rays away from each other.

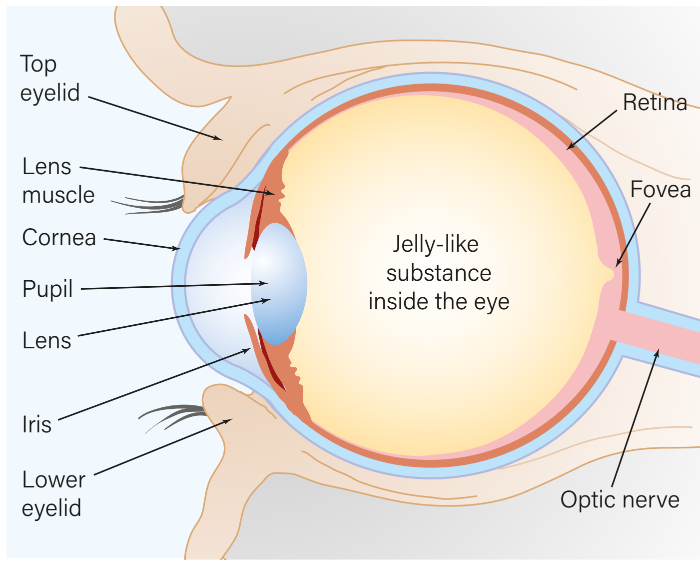
Light waves CONTINUED



- Light travels at different speeds in different mediums. When light passes from one medium to another it refracts, or bends.
- Lenses bend and focus light.
  - Convex lenses bulge outwards and make light rays converge (get closer together). The light rays meet at the focal point.
  - Concave lenses curve inwards and make light rays diverge (spread out).



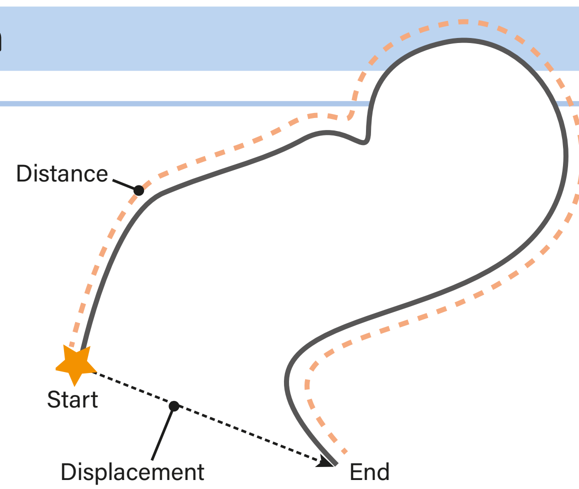
- The eye can make clear images of our surroundings. Having two eyes means we can see three-dimensional images and judge distances.
- The retina detects light, rods detect black and white for low light vision, and cones detect colour.



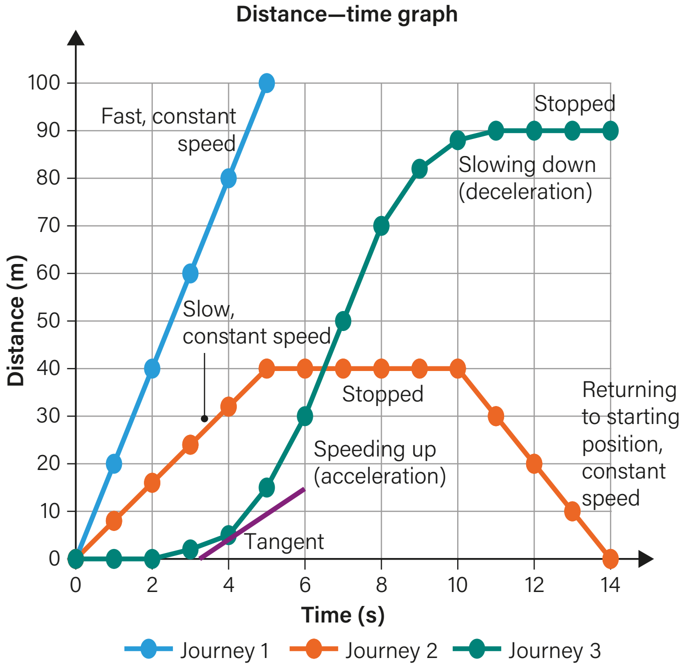
- Scientists learn about the universe by using telescopes to look at light from the electromagnetic spectrum.
  - Stars release most of their light as visible light. Hotter stars release higher-energy light towards the blue end of the spectrum.
  - Cooler stars release lower-energy light towards the red end of the spectrum.
  - Different wavelengths of light show different features of the universe.

Motion

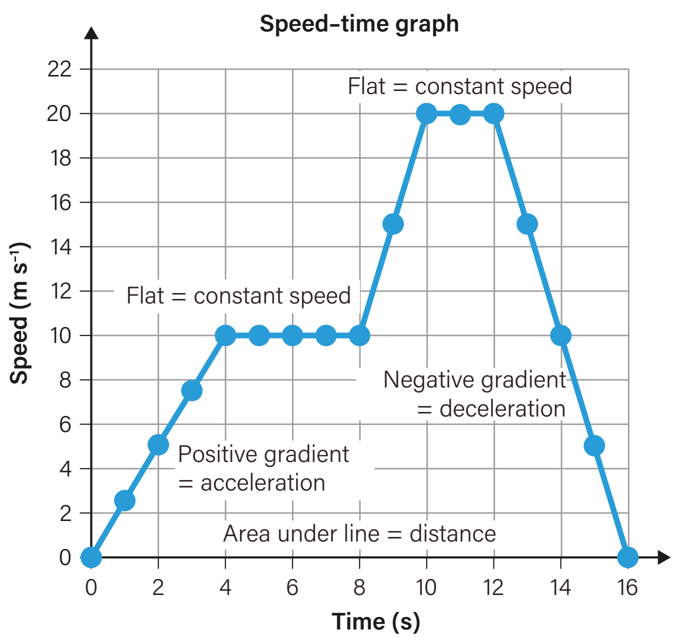
- Distance is how far an object travels. Speed is the distance an object travels divided by the time it takes to travel that distance. Speed is measured in metres per second ($m\ s^{-1}$) or kilometres per hour ($km\ h^{-1}$).
- Displacement is how far an object is from its initial starting position.



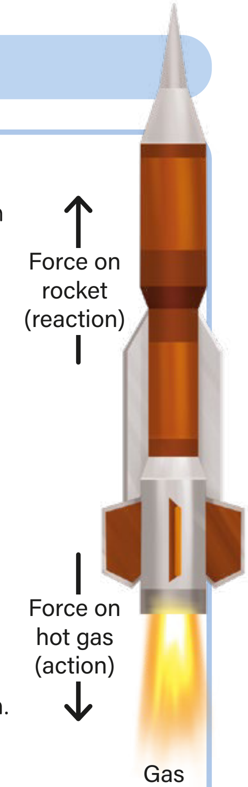
- Distance–time graphs represent motion.



- Acceleration is any change in speed or direction over time (i.e. speeding up, slowing down or turning).
- We can show speed, acceleration and distance on a speed–time graph (with time on the *x*-axis and distance on the *y*-axis).



- **Newton's first law:** an object at rest remains at rest and an object in motion remains in motion at a constant speed and in a straight line unless acted on by an unbalanced force that changes its motion. This is also known as an object's inertia.
- **Newton's second law:** the acceleration of an object is proportional to the force applied and inversely proportional to the mass of the object. $F = m \times a$, where F is force (N), *m* is mass (kg) and *a* is acceleration (m s^{-2}).
- **Newton's third law:** for every action, there is an equal and opposite reaction.
- The net force is all the forces acting on an object added together.



Waves and motion in context

- To create a scientific argument about how waves and motion have changed society requires using evidence to back up claims.

A claim

A claim is what you want to tell other people about and get them to believe.

Evidence

This can be first- and second-hand data, measurements, the results of investigations, research or reports, theories or laws.

Reasoning

You create an argument that links the evidence to your claim. Your argument must be persuasive, using evidence.

Masterclass

Steps in progression — 1 — 2

		1	2
Content	**Waves and motion**	Identify the speed of sound in air, using correct units.	Describe how the thickness or diameter of a guitar string affects the pitch.
Processes	**Conducting investigations**	Propose some safety considerations when conducting experiments to measure the volume of sound.	Describe what scientific equipment could be used to measure the amplitude of the sound waves from guitar strings.
Processes	**Processing data and information**	Using Table 7.11, construct a graph to demonstrate the relationship between the frequency and thickness (diameter) of the string.	Using your graph from step 1, describe in your own words the relationship between the frequency and thickness (diameter) of guitar strings.

Guitar strings vibrate to produce sounds

The frequency of sound produced by each string on a guitar is determined by the string's length, thickness and tightness (or tension). On a typical adult-size steel string guitar, each string has a particular frequency and diameter, as shown in Table 7.11. The speed of the wave in each string will also vary, depending on its tension and thickness and the material it is made of. The loudness (or amplitude) of the sound from a string is changed by how hard the string is plucked or played.

Playing a string will produce a base note such as 'E' or 'B'. The base note is the frequency or pitch of the wave produced by the string at its full length. However, the string will also produce harmonics. Harmonics create a richer sound.

Table 7.11: Guitar strings and their frequency with standard guitar tuning

String	Note	Frequency (Hz)	Diameter (mm)
1 (bottom string)	E	330	0.28
2	B	247	0.36
3	G	196	0.46
4	D	147	0.71
5	A	110	0.97
6 (top string)	E	82	1.24

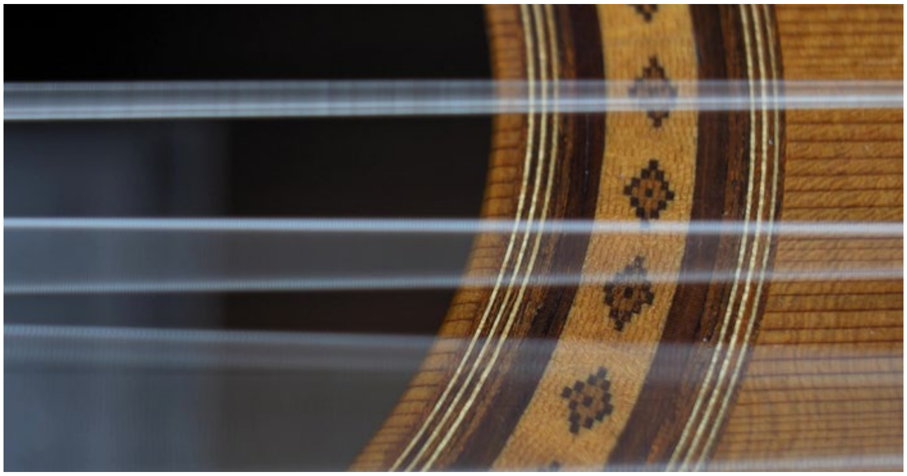


Figure 7.74: Guitar strings each produce a different frequency. Some strings have larger vibrations than others.

Demonstrate your understanding

3	4	5	
When pressing a string on a fret, explain why a shorter string creates a higher note. Consider the relationship between the frequency and the speed of vibration when a string gets shorter.	Explain the formula, including units, that demonstrates the relationship between frequency, speed and wavelength of sound waves.	Analyse how waves have impacted society in relation to music.	
Construct a method for an investigation to measure the frequency and diameter of each string on a guitar. Ensure your method produces accurate data.	Construct a results table for your investigation in step 3.	Research secondary data sources to find out and explain what harmonics are in more detail. Explain how they create richer sounds, and why they are important. Ensure you reference your sources.	Science how-to p. 408
Copy Table 7.11 and add a column to calculate the wavelength of the wave produced by each string.	Using the data in Table 7.11, explain how there can be two 'E' strings on the same guitar, and outline what is different about them.	Scientists want to record the frequency of each guitar string as accurately as possible. Suggest two methods that could be used, assuming the data from each method can be combined to produce a more accurate data set.	Science how-to p. 412

▲ **Figure 7.75:** Each string has a different thickness, which creates different frequencies.

▲ **Figure 7.76:** Pressing a string onto a fret shortens the string and increases the pitch.

The neck of the guitar has 'frets', which are little metal bars underneath and at right angles to the strings. When playing a guitar, the length of a string can be shortened by pressing it down onto the fret. This action changes the note being played. The shorter the string, the higher the pitch or frequency of the note. This means that if you press a string against a fret, then keep moving up to the next fret closer to the body of the guitar, the note played will continue to get higher, as the string gets shorter as you move past each fret.

Focus area 8

8.0 Data science 2

Many companies use data to make claims, or present data as though it supports their conclusions. However, data is sometimes used or manipulated in a way that can make pseudoscientific or invalid claims seem factual. So, how can we ensure that we are not being fooled by the data?

In this focus area, we will consider the use of scientific knowledge and data in making evidence-based decisions and in verifying the legitimacy of claims. We will analyse data to identify trends, patterns and relationships, and to draw conclusions. We will also learn how to communicate scientific arguments with evidence, using appropriate language and terminology.

Figure 8.1: There are many tools used for gathering, using and analysing data across a range of different industries.

Learning Ladder

The Learning Ladder contains the scientific content and processes you will learn in this focus area. Each area has five levels of progression. To move to higher levels, you need to practise activities at the earlier levels. This will help you develop the ability to complete tasks that are more complex.

Steps in progression	Content: Data science 2	Working scientifically processes: Analysing data and information	Working scientifically processes: Problem-solving	Working scientifically processes: Communicating
5	I can assess the use of datasets to verify scientific claims.	I can evaluate conclusions based on the quality of data.	I can evaluate scientific claims based on evidence.	I can evaluate scientific findings based on secondary evidence and arguments.
4	I can discuss the features of datasets and link these to their uses.	I can assess data and information for accuracy, reliability and validity.	I can assess problem-solving strategies used to solve an identified problem.	I can present scientific findings using appropriate conventions for specific audiences.
3	I can explain how data can help to support scientific claims.	I can draw conclusions based on patterns in data and information.	I can use given criteria to find solutions to scientific problems.	I can construct a range of appropriate scientific presentations based on first-hand and second-hand data and information.
2	I can describe how data can be used in a number of different ways.	I can explain relationships between datasets and information.	I can explain scientific problems and phenomena using cause-and-effect relationships.	I can use digital technologies to organise and present data and information.
1	I can identify scientific claims and data.	I can describe trends from collected data and information.	I can propose solutions to familiar scientific problems.	I can select appropriate ways to communicate information.

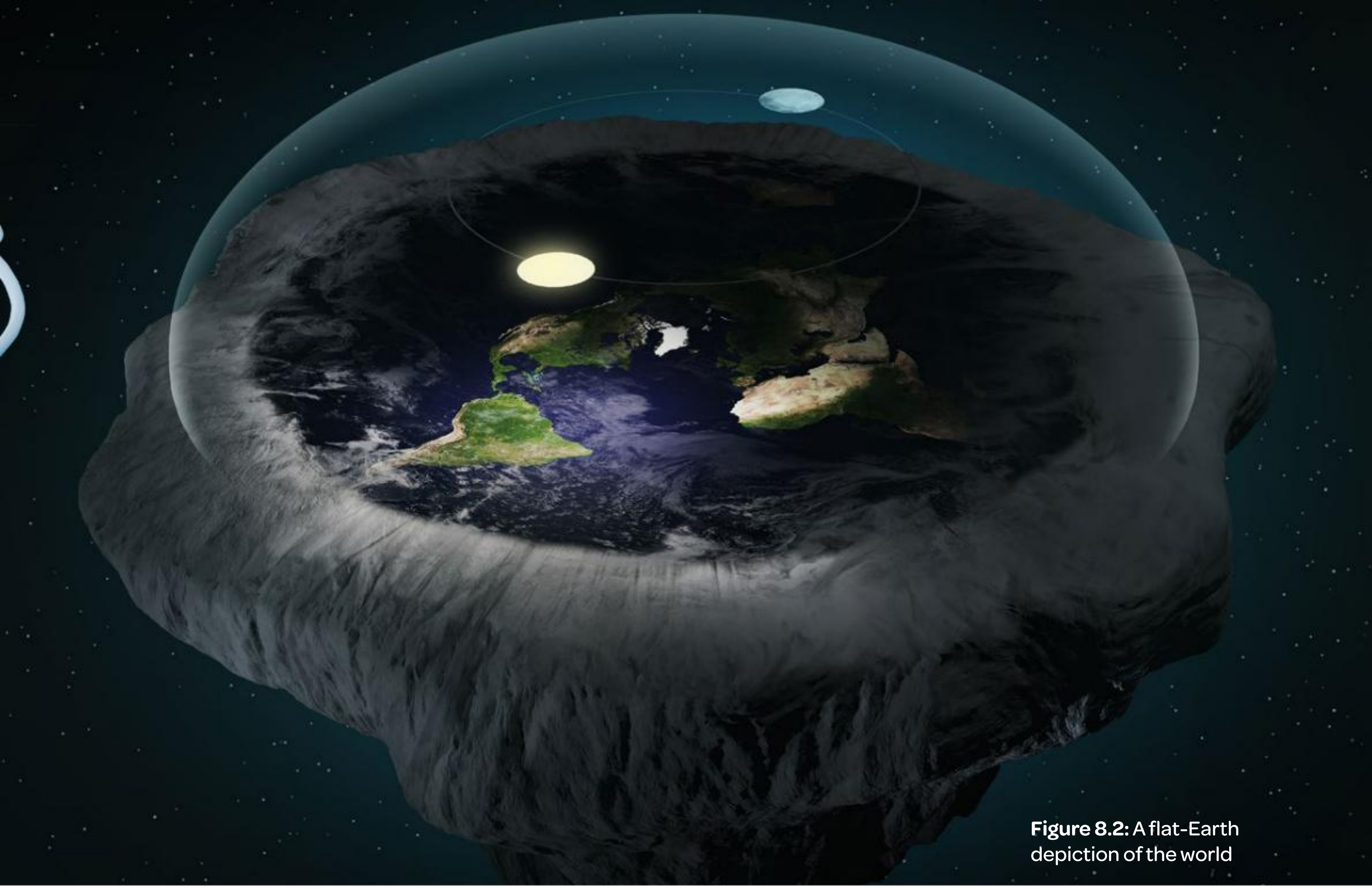


Figure 8.2: A flat-Earth depiction of the world

Figure 8.3: Some people try to use data to show that Earth is flat, not round, but scientific experimentation of testable questions shows that their claims are false. Photos of Earth taken from space show its spherical shape.

8·1 ▸ Data recap

Learning intention

At the end of this lesson, I will be able to recall what data is, and how it can be collected and presented.

Key terms

big data: large, diverse sets of information that grow at increasing rates

continuous data: data that can take any value along a continuum or between fixed values

data: facts and information collected for reference or analysis

discrete data: data that can only take certain values; fixed values; for example, a quantity count

first-hand investigation: an investigation where the data is collected by the investigator

qualitative data: data with qualities or characteristics that can be observed and described

quantitative data: information based on numbers that can be counted, measured or represented by numbers

second-hand investigation: an investigation that uses data previously collected in a separate investigation

Data is all around us. It is used in our devices and informs many of the decisions we make and much of the information that we process.

Data can be quantitative or qualitative

The term **data** refers to facts and information that can be collected and analysed. Collecting and analysing data allows us to interpret findings and draw conclusions. In its simplest form, data can be split into two categories.

Qualitative data is non-numerical qualities or characteristics that can be observed and described. This could be as simple as asking people to describe why they like their favourite food. Their description is an example of qualitative data.

Quantitative data is numerical information that can be counted, collected and represented. This data can be further caregorised as discrete data or continuous data. **Discrete data** has fixed values: the number of students that attend class each day is an example of discrete data. **Continuous data** can have any value within a range. If everyone in your class participated in a 400 m running race, the range of finishing times would be continuous data (Table 8.1).

Table 8.1: Quantitative, continuous data relating to times in a 400 m race

Race position	Time (s)
1	95.32
2	97.21
3	98.37
4	102.02
5	108.98
6	109.16
7	119.53

There are different ways of collecting and presenting data

The type and location of data, and the availability of resources, all affect how data is collected.

First-hand investigations

When a person or a scientist directly collects facts or information about a particular topic, they conduct a **first-hand investigation**. First-hand investigations aim to answer investigable questions (see Section 8.2) and are conducted by the person asking the questions. Data is collected directly from the results of the investigation and recorded by methods such as tabulation and graphing.

Second-hand investigations

Sometimes it is not possible to conduct a first-hand investigation because of a lack of resources and/or feasibility, or because there have already been many first-hand investigations conducted on a particular topic and the results of those can be readily accessed. In this case, you can use second-hand data for a **second-hand investigation**. Second-hand data has previously been collected and recorded and is now available for others to look at and interpret. You have seen second-hand, and even tertiary, data in textbooks and articles.

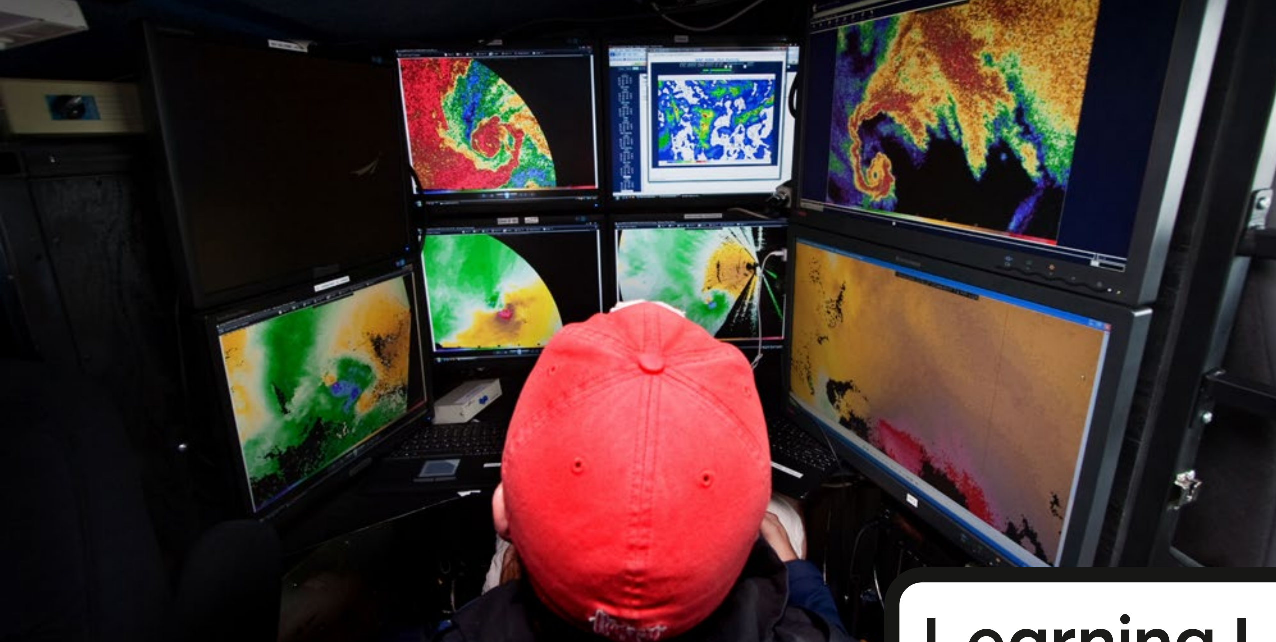


Figure 8.4: Weather radars are programmed by meteorologists to use big data to make predictions about patterns and to show us likely levels of rainfall.

Big data

With digital technologies becoming more and more prevalent, scientists can use computers to collect large amounts of data from multiple sources. Very large and very complex datasets are known as **big data**. Big data is analysed and interrogated by computers to generate data-driven insights that can underpin the results of search engines such as Google. Big data is the reason you get search suggestions when you are searching the internet.

Scientists use data to draw conclusions and model processes

Once collected, data is typically analysed to look for patterns, or trends. Interpreting what collected data tells us allows us to draw conclusions, and then to make predictions about real-world phenomena.

Scientists use their conclusions about many real-world phenomena to make models, such as weather models and climate models. Big data is collected about past and present weather patterns, and this data is interpreted into conclusions and then used to make predictions that generate models of what our weather conditions might look like in the future.

Figure 8.5: As students, you collect first-hand data when you conduct investigations during science lessons.

Learning Ladder

Data science 2

1. Identify a claim made in this section on a topic we can learn about using data.
2. Describe how data on the topic identified in Question 1 provides us with evidence.
3. Explain how the evidence identified in Question 2 helps us to support conclusions about this topic.
4. Discuss the features of big data, including how it can be collected.

Communicating

see page 429

1. Propose an appropriate quantitative measure to group the people in your class.
2. Construct a digital graph that could represent the data shown in Table 8.1.
3. Construct a poster presentation that could be used to show the differences between quantitative and qualitative data.
4. Explain how your poster in Question 3 could be modified so that it could be used to teach a Year 8 student about the different types of data that can be collected.

In context

Big data is collected by computers and used for many purposes, including artificial intelligence (AI). Propose why mining the internet to collect big datasets that allow AI to generate scientific responses to questions may result in incorrect information being distributed and used.

Success criteria

- I can distinguish between qualitative and quantitative (discrete and continuous) data.
- I can explain how data can be collected and used by scientists.

8·2 ▸ Investigable and non-investigable questions

Learning intention

At the end of this lesson, I will be able to construct questions that can be investigated.

Key terms

dependent variable: the thing that is measured in an investigation; its value depends on changes in the independent variable

independent variable: the thing that is deliberately changed in an investigation; its value does not depend on any other variable

investigable question: a clear, concise question that contains a single independent and dependent variable, and centres the research for an investigation

non-investigable question: a question that cannot be investigated scientifically

Investigation 8.2

What if Earth stopped rotating for 1 second?, page 594

Content group: Investigating questions and claims

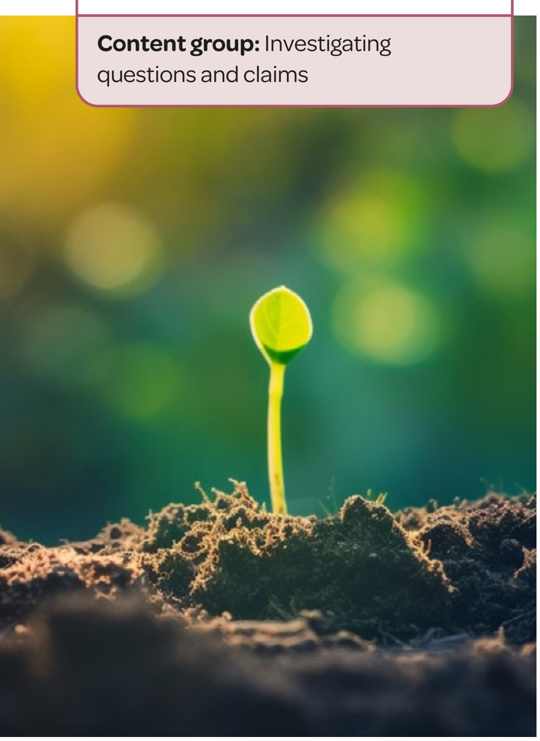


Figure 8.6: Many factors might influence plant growth.

Some questions can be investigated scientifically (**investigable questions**), while others cannot (**non-investigable questions**). For example, it is not possible to investigate why a candle melts when it burns. But we could construct an investigation for the question: 'How does the thickness of candles (of the same length) affect how long they burn?' A simple experiment can answer the question.

A scientific question can be investigated

Scientific questions need to be written using one specific **independent variable** and a **dependent variable**, so they can be answered. You can use the following prompts to start a scientific question:

- What happens ...?
- How does ...?
- What effect ...?
- Which type of ...?
- Why does ...?
- What is ...?

Some examples of scientific questions that can be investigated are:

- *How does salt in water affect the ability of an object to float in it?* The independent variable is the amount of salt, and the dependent variable is an object's ability to float.
- *What factors can affect the growth of plants?* 'Factors' is the independent variable, which can be replaced with a single factor (e.g. sunlight or water), and the growth of the plants is the dependent variable. (See the Science how-to section on pages 401–2 to learn more about constructing scientific questions.)

A scientific question needs to have an independent variable that can be changed to see how the change affects the dependent variable. The scientific question can be answered through an experiment or through research. However, some scientific questions are non-investigable. For example: 'Which came first: the chicken or the egg?'

Steps in developing a scientific question

Follow these steps when developing a scientific question:

- Consider the reason for the investigation.
- Decide on the dependent variable and what factors might affect it.
- Consider all the aspects that could be changed (independent variables) and decide which one you will change.
- Make each of the independent variables into a separate question, using the previous prompts.
- Review all your questions and decide which one to pursue. It is expected scientific practice to vary one aspect at a time to produce valid results.

Table 8.2: A question that seems scientific but has many independent variables would need to be altered so that a first-hand investigation can be conducted

Question: What factors affect the growth of plants?		
Independent variable	**Dependent variable**	**Scientific question**
Sunlight exposure	Amount of plant growth	How does the amount of sunlight exposure affect plant growth?
Amount of water		How does the amount of water affect plant growth?
Soil type (clay, sand, silt)		How does soil type (clay, sand, silt) affect plant growth?
Soil pH		How does soil pH affect plant growth?

For example: *What factors can affect the growth of plants?* The reason for conducting the investigation may be related to improving the growth of crops to generate more food, which can be distributed to consumers. Table 8.2 shows four separate independent variables that could become the focus of the investigation. It is important to select only one variable to investigate.

If the variable selected is sunlight, then the water levels, soil composition and soil pH should be kept consistent in all the plants across the entire investigation. The only factor that should be varied is the amount of sunlight that the plants are exposed to each day, over the period of time they are grown for.

By implementing these processes, you can be confident that your investigation will address your scientific question. See the Science how-to section on page 424 to review the factors that make an investigation valid.

Evidence from investigations affects the conclusions

The evidence found in first-hand investigations can influence the conclusions we make and how they relate to our hypotheses. For example, using the factors affecting plant growth investigation, the level of confidence in the conclusion depends on the way in which the experiment is conducted. If the only different factor is the amount of sunlight (the independent variable) and there is clear evidence that plants that receive more sunlight grow better (the dependent variable), then there would be strong confidence in the conclusion. If several factors were varied in the same experiment, we would not know which factor affected the growth of the plants.

Learning Ladder

Data science 2

1. Classify the following questions as investigable or non-investigable:
   - **a** How does temperature affect plant growth?
   - **b** How tall do plants grow?
   - **c** What makes plants stop growing?
   - **d** How does sulfate concentration in fertiliser affect plant growth?
2. Identify evidence that could be collected to support the claim, 'Plants need sunlight to grow.'
3. Describe how you can use data from an investigation as evidence to support your conclusions.
4. Explain how conclusions from investigations can be linked to scientific claims.

Problem-solving

see page 425

1. Propose a solution to the question, 'What effect does the amount of water received have on plant growth?'
2. Explain how the components of an investigable question are linked, so that they can be tested in a first-hand investigation.
3. Propose a set of criteria you could use to investigate the effect of salt water on an object's ability to float.

In context

Use your understanding of investigable questions to construct a scientific question that you could investigate and explain how it would help to solve an identified problem in your home. See the Science how-to section on pages 401–2 for help with constructing your questions.

Success criteria

- I can construct questions that can be tested in first-hand investigations.
- I can explain how investigation data can be used to draw conclusions.

8·3 ▸ Validity and reliability of online content

Learning intention

At the end of this lesson, I will be able to determine whether online content is valid and reliable.

Key terms

biased data: data that is incomplete, skewed or inaccurate

reliable data: data that is consistently similar when multiple trials of the same investigation (or search) are repeated

valid data: data that is reliable and accurate and meets the criteria of the investigation

Investigation 8.3

Do red cars go faster?, page 595

Content group: Investigating questions and claims

Anyone can post material on the internet, so it is important to consider whether that information is accurate; that is, valid and reliable. '**Validity**' refers to the accuracy of the information. '**Reliability**' means that the information can be replicated consistently. Information can be reliable and/or valid. It is possible to have information that is reliable (i.e. consistently replicable) but not valid, but if it is not reliable it cannot be valid. For example, if I set my alarm clock to be 10 minutes fast, then the time shown on the clock is reliable because it is consistent. However, it is not valid because the time is always incorrect.

Data should be valid *and* reliable

There are six main criteria used to judge the validity and reliability of online content. They are listed in Table 8.3.

Table 8.3: Criteria for judging the validity and reliability of material on the internet

Criteria	Questions addressed
Audience	Who is the target audience? Are they academics? Is it people who are influenced for profit?
Authority	Who created the site? What are their credentials? Who is sponsoring the site? Are there ads on the site?
Accuracy	Is the information accurate? Does the author cite sources? Are the sources reliable? Is the author a recognised expert in the field? Is the author from an educational institution or a credible organisation? Has the information been peer reviewed?
Objectivity	Is it **biased data**? Is there bias in the information? Are all sides of the argument presented? Is it a personal website?
Currency	Is the information up to date? Has it been updated recently?
Usability	Is the site well organised and professional looking? Are there spelling or grammatical errors?

▼ **Figure 8.7:** Information published by universities is typically valid and reliable.

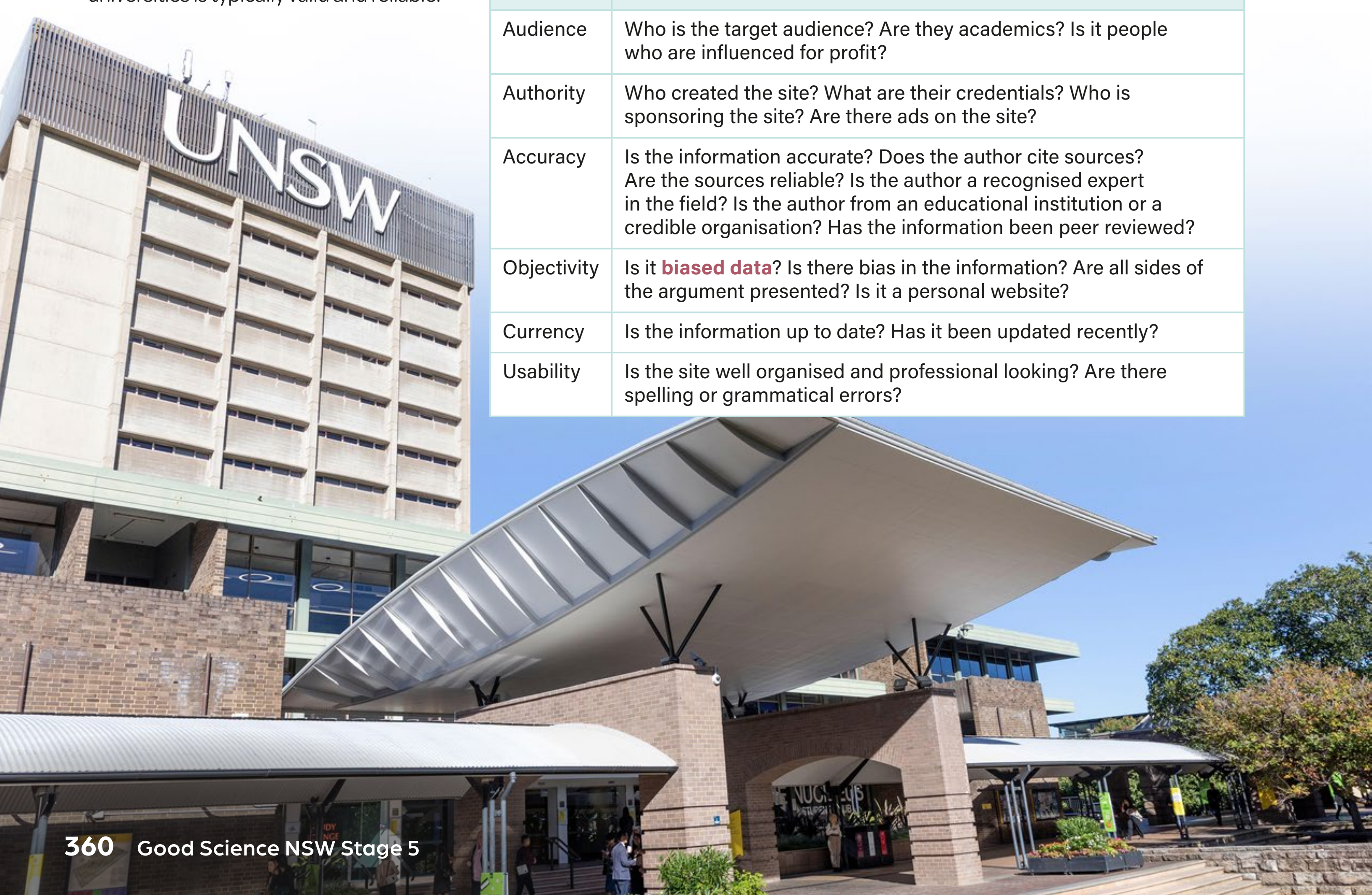


Figure 8.8: The results of search engines need to be carefully considered for reliability and validity.

Look for sites that are linked to reliable organisations such as governments, non-profit agencies and educational institutions. Sites with advertising – particularly advertising that is not associated with the information you are trying to source – are less likely to contain valid data. Consider that the greater the number of ads, the less valid the site. More information about assessing the reliability and validity of data is available in the Science how-to section on pages 423–24.

Assess results from search engines for reliability

Search engines use your previously entered searches to filter the information they provide. So, two people searching for the same information using the same search engine may not get the same results. Consider using a variety of search engines when sourcing information. All search engines will use your search history to make recommendations on your new searches. Reliable data will be consistent across multiple sources from different search engines.

When evaluating information obtained through an internet search, consider the 'W' questions: Who? What? When? Where? How? and Why? Although 'how' does not start with a 'W', it does have one! This will assist in determining reliability and validity. Use Google Scholar for a more reliable and valid search for information.

Learning Ladder

Data science 2

1. Identify a feature of valid data.
2. An article is downloaded from the internet. Describe how you would determine if it is reliable.
3. Explain why it is important to have data that is valid and reliable.
4. Discuss how the steps of determining reliability and validity could be applied to a *National Geographic* article.

Problem-solving

see page 425

1. Your kitchen scales are set to zero with the mixing bowl on it. You use them to weigh 10 packets of sugar and get the same mass for each one. However, the masses are all incorrect. Explain why the measurements are reliable but not valid.
2. A ruler is used to measure several lengths of wood. The edge of the ruler is put on the end of the piece of wood and the measurement is taken. However, the ruler has a space before the zero. Propose a way to improve the validity of these results.
3. When researching to solve a problem, describe how you would determine if the research is valid and reliable. Explain why having set criteria to make this determination is important.

In context

Think about your favourite animal. Conduct an online search to find three sources that provide information about its habitat, diet and adaptations. Using the criteria in this section, assess each source for its reliability and validity, and rank the sources from highest to lowest validity and reliability.

Success criteria

- I can evaluate the validity and reliability of online content.

8.4 ▸ Developing and investigating claims

Learning intention

At the end of this lesson, I will be able to develop an experiment to investigate a claim.

Investigation 8.4

Sugary drinks and teeth, page 596

Content group: Investigating questions and claims

Figure 8.9: Real teeth cannot be used to investigate the claim about sugary drinks and teeth, so eggshells will be used instead.

Many parents tell their children that sugary drinks are bad for their teeth and so they should not drink them on a regular basis, and that cleaning their teeth regularly will reduce stains. We can investigate this claim with a series of experiments. The details for the experiments are in Investigation 8.4.

Figure 8.10: Drinking too many sugary drinks is linked to tooth decay.

The claim: sugary drinks are bad for your teeth

We will investigate this claim by developing some investigable questions, as discussed in Section 8.2, and plan an investigation and conduct an experiment to determine the results. We propose to develop an investigation that examines the effect of sugary drinks on tooth structure, using eggshells rather than human teeth. The amount of time it takes for the drink to affect an eggshell will also be considered, as will the effect of brushing and using toothpaste to reduce staining. So, there are several aspects to be considered in designing the investigation.

Conduct research into the claim

The next step is to conduct some research into the claim. An internet search would quickly provide several articles that support this claim. Ensure you use the guidelines in Section 8.3 to determine the validity and reliability of the information. The data will show a strong correlation between sugary drinks and issues with teeth. The Australian Dental Association website states: 'Sugary drinks can affect the teeth by causing tooth decay and tooth erosion. These drinks include soft drinks, energy drinks, sports drinks, pre-made iced teas, and fruit juice. The best choices for tooth-friendly drinks include water and milk.' The website advises eating fruit rather than drinking juice and notes that sugar-free soft drinks are not healthier because they are quite acidic, which can cause tooth erosion. This site is reliable and valid, so these are the claims that we will set out to investigate.

There are many aspects to consider when designing the investigation

Because it would be difficult to obtain real human teeth, we will use eggs in our investigation. Teeth are made of an outer shell of calcium, and this is quite similar to eggshell, which is calcium carbonate. Be sure to use fresh eggs that will sink into the liquid.

The egg will be removed, examined and photographed after 30 minutes, and again after 24 hours. The results will be put into Table 8.4. Six types of drink will be used.

Table 8.4: Experimental results

Type of drink	Description of eggs after	
	30 minutes	24 hours
Cola		
Cordial		
Fruit juice		
Non-cola sugary soft drink 1		
Non-cola sugary soft drink 2		
Tap water		

The choice of drinks affects the confidence of the claim

Water will be used as a baseline liquid. It is neutral, contains no sugar or added substances, and will show whether submersing the egg in liquid has any effect. A cola-based drink and two non-cola, sugary soft drinks will be used, plus fruit juice and cordial. Including only sugary drinks and water helps to increase the confidence of the claim.

Consider the strength of your results

The results of the experiment show that all the drinks except water have an effect on the colour and condition of the eggshell. Extrapolating these results from eggshells to teeth would suggest that similar effects would be observed on teeth exposed to these drinks. Further, the results suggest that sugary drinks are not good for teeth.

When conducting any investigation, scientists need to consider the strength of their evidence. Evidence is considered strong if the investigation is relevant to the question, if the results are consistent, and if they can be applied to the science behind the concept. In this case, our investigation should help us to make a relatively confident claim.

Figure 8.11: A range of different drinks on the commercial market contain large amounts of sugar and could be bad for your teeth.

Learning Ladder

Data science 2

1. Identify the claim that is being investigated in this section.
2. Describe the purpose of the experiment.
3. Explain why water is used as one of the drinks.
4. Discuss which drink you think will have the greatest effect on eggshells and therefore on teeth.
5. Evaluate how data has been processed and interpreted to form a conclusion about the effect of sugary drinks on teeth.

Problem-solving *see page 425*

Before answering the following questions, read Investigation 8.4 on page 596.

1. Propose some other drinks that could be tested.
2. Explain why the eggs are checked after 30 minutes and again after 24 hours.
3. Justify waiting 30 minutes before checking, rather than after 5 minutes (the time taken to drink a drink).
4. Assess the results and the criteria that indicate the conclusion is correct.
5. Evaluate the method used in the experiment and suggest any possible modifications.

In context

Design another investigation that examines the impact of a specific type of drink on tooth decay. Make sure your investigation is valid, so you can have confidence in your claim. (Use the Science how-to section on page 424 to help you with your experimental design.)

Success criteria

- I can design an experiment to investigate a claim.

8.5 ▸ Constructing scientific arguments to support claims

Learning intention

At the end of this lesson, I will be able to construct scientific arguments to support or disprove claims.

Key terms

anecdotal evidence: evidence without scientific basis and usually in the form of personal accounts

causation: when one variable causes an effect in another variable

correlation: a mutual relationship between two things that may or may not be causal

experimental data: information collected by a measurement from a scientific experiment or controlled study

observational study: a type of study in which individuals are observed or certain outcomes are measured

randomised controlled trial: a study in which a number of similar people are randomly assigned to two (or more) groups to test a specific drug, treatment or other intervention

Investigation 8.5

Where did Earth's water come from?, page 597

Content group: Investigating questions and claims

▲ **Figure 8.12:** Many studies provide supporting evidence that consuming fruit and vegetables is linked to better cardiovascular outcomes.

It is easy to make a claim, but for it to be accepted as scientific, there needs to be a scientific argument supporting the claim. The more scientific evidence there is, the more support there is for the claim.

There are five steps when investigating a claim

When presented with a claim to investigate, five main steps are required:

1. **Identify the claim:** Define specifically what it is you are going to investigate.
2. **Gather evidence:** Collect data and information through experiments, observations or from existing research. Ensure that the data is valid and reliable. Consider the type of evidence, such as quantitative data (numerical measurements), qualitative data (descriptive observations) or **anecdotal evidence** (personal accounts).
3. **Analyse the evidence:** Use statistical methods where possible to quantify the strength of the evidence and how it connects to the claim. Be sure to differentiate between **correlation** (a relationship between variables) and **causation** (one variable causing a change in another). These aspects will be discussed further in Section 8.11.
4. **Reasoning:** Explain how the evidence links to the claim. Consider the possibility of other explanations or counterarguments. Provide any reasoning.
5. **Construct the argument:** There are four main parts when constructing an argument:
   - **Introduction:** Clearly state the claim and include any context.
   - **Body:** Present and analyse the evidence using logical reasoning.
   - **Counterarguments:** Discuss any counterarguments or any limitations of the evidence and how it will be included.
   - **Conclusion:** Summarise how the evidence supports the claim, reinforcing the implications of the findings.

Example of a scientific argument

Claim: Eating more fruit and vegetables improves cardiovascular health.

Evidence

- **Biological mechanism:** Fruit and vegetables are 'superfoods'. Rich in antioxidants, vitamins and fibre, they are known to improve heart health.
- **Study 1:** A **randomised controlled trial** showed that individuals who increased their intake of fruit and vegetables lowered their blood pressure and cholesterol levels.

- **Study 2:** Observational studies indicate that populations with higher fruit and vegetable consumption have a lower incidence of heart disease.

Reasoning

- **Link to claim:** The randomised controlled trial provides strong causal evidence that increasing fruit and vegetable intake directly improves cardiovascular health. Observational studies support this by showing a correlation between high consumption of fruit and vegetables and lower rates of heart disease in various populations.
- **Alternative explanations:** Other factors, such as physical activity and overall diet quality, might also contribute to cardiovascular health. However, the consistency of results across different studies and the presence of a biological mechanism strengthen the case for the specific role of fruit and vegetables in improving cardiovascular health.

Constructed argument

- **Introduction:** Cardiovascular health is influenced by various factors, including diet. This argument evaluates the claim that increasing fruit and vegetable consumption improves cardiovascular health.
- **Body:** Evidence from a randomised controlled trial demonstrates a direct improvement in cardiovascular markers with increased fruit and vegetable intake. Additionally, observational studies provide a broader context, showing that populations with higher fruit and vegetable intake tend to have better cardiovascular outcomes. The biological mechanisms of fruit and vegetables, such as antioxidants and fibre, further support this claim.
- **Counterarguments:** While physical activity and overall diet quality also affect cardiovascular health, the specific contribution of fruit and vegetables is well supported by the evidence. The comprehensive nature of the evidence, including direct studies and biological explanations, outweighs potential counterarguments.
- **Conclusion:** The collected evidence strongly supports the claim that increasing fruit and vegetable consumption benefits cardiovascular health. The alignment of experimental data, observational studies and biological mechanisms provides a strong basis for this conclusion.

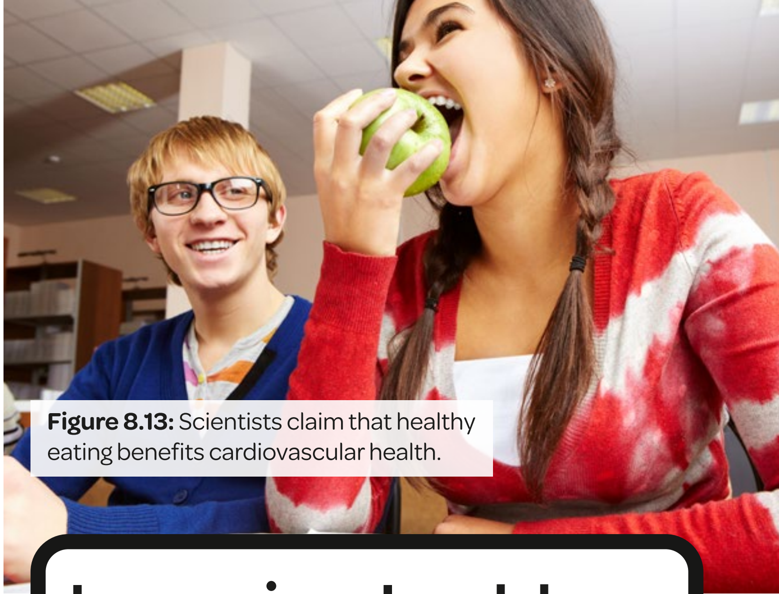


Figure 8.13: Scientists claim that healthy eating benefits cardiovascular health.

Learning Ladder

Data science 2

1. Identify the five steps used when investigating a claim.
2. Describe how to construct an argument to support a scientific claim.
3. Explain the factors in the counterarguments for the fruit and vegetable investigation.
4. Discuss specific features that provide strong supporting evidence for the claim that eating fruit and vegetables benefits cardiovascular health.
5. Assess the validity of the conclusion drawn in relation to increased fruit and vegetable consumption contributing to improved cardiovascular health.

Communicating

see page 429

1. Describe an appropriate format for a presentation on the benefits of fruit and vegetable consumption.
2. A restaurant wins the 'Best in Town' award. To collect evidence of this claim, you ask your friends to rate all restaurants in town on a scale from 1 to 5. Prepare a spreadsheet to collect the data relating to the claim.
3. Construct your presentation from Question 1 to show how an individual could incorporate more fruit and vegetables into their diet.
4. Present the findings from Question 2 to a group of your peers.

In context

Before 1999, the age of the universe was estimated to be between 7 and 20 billion years. Advances in technology and new techniques now mean the estimated age is 13.7 billion years ± 200 million years. Investigate the advances and how the age of the universe is determined.

Success criteria

- I can follow the five investigative steps for constructing scientific arguments to support or disprove claims.

8·6 ▸ Science versus pseudoscience

Learning intention

At the end of this lesson, I will be able to distinguish between scientific and pseudoscientific claims.

Key terms

ecliptic: the Sun's apparent annual path as observed from Earth

pseudoscience: beliefs mistakenly regarded as being based on scientific theory

science: the study of the natural and physical world through observation, experimentation and testing theories against evidence

Investigation 8.6

The influence of advertising, page 598

Content group: Pseudoscience

People can claim that a theory is based on **science** when it is not. Sometimes an idea or ideology is accepted as being based in science simply because it has been around for a while or people believe it without scientific evidence. These ideas are referred to as **pseudoscience**. Influencers often present pseudoscientific theories on their platforms.

Astrology is a pseudoscience about the stars

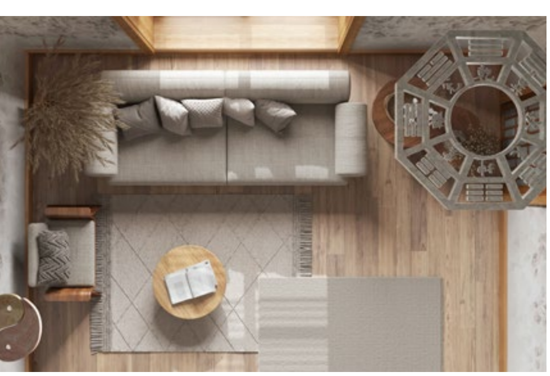
Astrology is the study of the movements and relative positions of celestial bodies: the planets, Sun, Moon and stars. It is believed that these movements can influence people's personalities and lives. The premise is that the position of the celestial bodies at the time of your birth determines your personality, among other traits.

The Babylonians (500 BCE) divided the zodiac, a band of the sky 9 ° on either side of the Sun's **ecliptic**, into 12 astrological signs. A significant amount of science was involved in determining the band and dividing it into 12 sections. However, because of changes in the orientation of Earth's axis, the astrological signs are no longer where the Babylonians first defined them. For example, the point of Aries is now in Pisces.

There is no scientific basis for astrology even though it appears daily in many media sources. Conversely, the scientific practice of *astronomy* gives us information about the universe that scientists can measure and gather supporting evidence for, such as the size, temperature and components of stars, and the distances to other planets and galaxies.

▲ **Figure 8.14:** Astrology is supposed to determine how your day will proceed.

▼ **Figure 8.15:** Feng shui suggests the 'best' way to set up a room to create a harmonious flow of energy.



Feng shui claims that a flow of good energy improves health, relationships and prosperity

Feng shui is an ancient Chinese practice that is based on establishing harmony and balance between a person and their environment by considering energy flows within a physical space. In the modern world, this predominantly takes the form of the specific arrangement of the items in different rooms in a person's home.

One aspect of feng shui is 'commanding position', which is the part of a room that is furthest from the door and not directly in line with it. Objects such as beds, desks and lounges, where the occupant spends most of their time in a room, should be placed in the commanding position, which is said to help promote security and control in their life. The type, arrangement and colours of objects in the home also supposedly help to promote health, wealth and success.

There is currently no scientific evidence, from identified and verified first-hand studies, that proves the effectiveness of this practice.

Fad diets have limited scientific basis

Social media is rife with fad diets that guarantee to promote weight loss. Unfortunately, most are without a scientific basis and are more likely to be pseudoscience. Some examples of fad diets are:

- *Alkaline diet:* replacing meat, grain and dairy with fruits, nuts and vegetables to make the body more alkaline, even though parts of the body need to be acidic.
- *Carnivore diet:* only eating meat, fish and chicken, and excluding fruit, vegetables, grains, etc., which are linked to good health.
- *Eat right for your blood type:* eating foods that are randomly associated with your blood type.
- *Master cleanse:* consuming a liquid-only diet of water, lemon juice, maple syrup and cayenne pepper for 10 days.
- *Paleo diet:* consuming a diet based on our ancestors' eating patterns.
- *Whole 30:* a 30-day elimination diet where grains, dairy, soy, sugar and alcohol are eliminated, and then some are reintroduced after 30 days.

Scientifically speaking, sustained weight loss can only occur over time using a balanced diet.

Water divining is not effective

An excellent example of pseudoscience is the practice of water divining (dowsing), where a dowser attempts to locate groundwater or other buried materials using a divining rod. The water diviner walks across the land and identifies the location of the water. This practice is not supported by science, which shows that it is no more effective than random chance.

Pseudoscientific claims are not based on scientific evidence

While the above ideas might sound convincing, they are all considered pseudoscience for the same reason: there is no supporting scientific evidence for them. For a claim to be considered scientific, it needs to be supported by evidence collected using valid methods of first- and second-hand investigation. Supporting data must be considered accurate, reliable and valid by the scientific community.

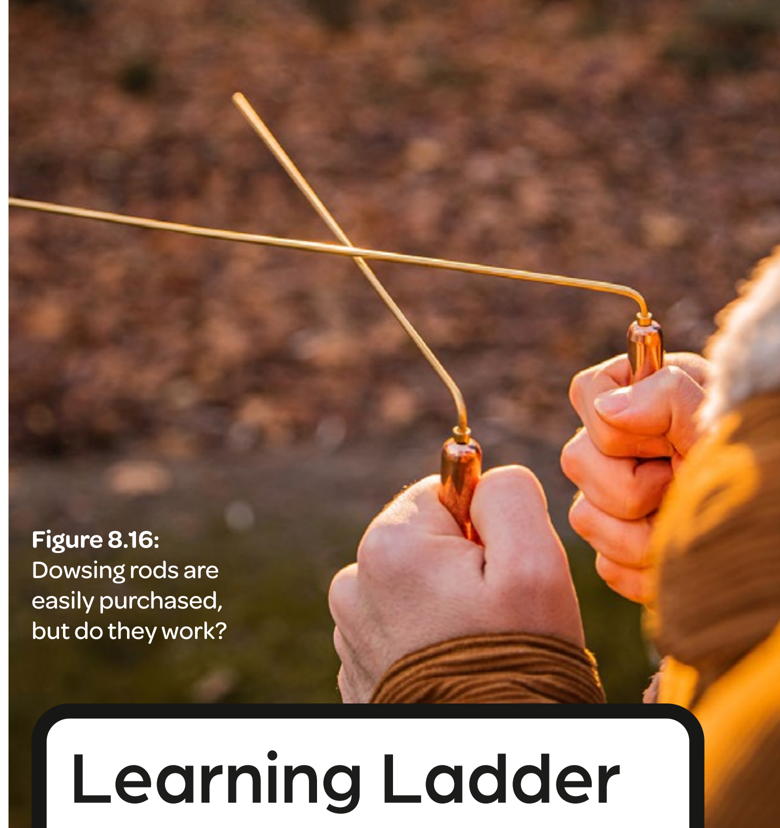


Figure 8.16: Dowsing rods are easily purchased, but do they work?

Learning Ladder

Data science 2

1. Identify an example of a pseudoscientific claim.
2. Describe the conditions that indicate astrology is a pseudoscience.
3. Explain why valid data is needed to support scientific claims.
4. Discuss another pseudoscience mentioned in this section and assess its validity.

Analysing data and information

see page 420

1. Describe the common weight trend promised by fad diets.
2. Explain the prevalence of fad diets on the internet.
3. Propose two reasons why the carnivore diet is a fad diet.
4. Assess two different fad diets and draw conclusions as to whether either diet has any scientific merit. (Hint: Is the information accurate, reliable and valid?)
5. Evaluate if a given diet from this section is a fad diet, or if it has a scientific basis, by determining the accuracy, reliability and validity of the information and draw a conclusion.

In context

Cryptozoology is considered to be a pseudoscience. Collect evidence to support or refute the claim and present this evidence as a scientific argument.

Success criteria

- I can distinguish between scientific and pseudo-scientific claims.

8.7 ► Pseudoscience in the media

Learning intention

At the end of this lesson, I will be able to recognise pseudoscience in the media.

Key terms

influencer: a person with an online following who promotes products or services through social media to their followers to influence their purchasing behaviours

social media: online platforms that allow individuals and groups to publicly share content to an audience of followers

Investigation 8.7

Earth is flat!, page 599

Content group: Pseudoscience

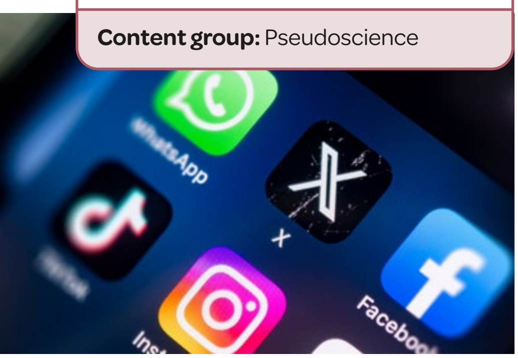


Figure 8.17: The existence of many social media platforms makes it easy for pseudoscientific content to become widespread.

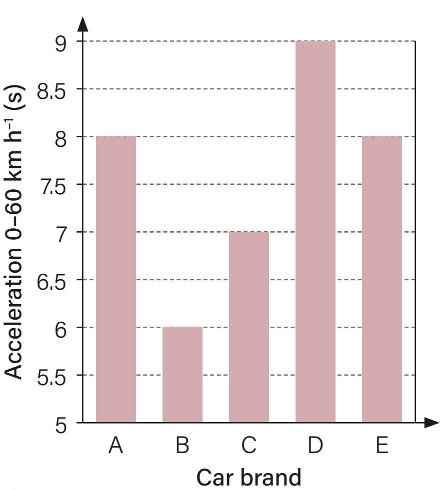


Figure 8.18: How the data in Table 8.5 might be represented in a column graph in a TV advertisement or an infomercial.

The internet has allowed for an explosion in the number of platforms that can be used to share large amounts of data and information. In the mid–2000s, social media apps such as Facebook and Twitter (now known as X) began to gain popularity among a wider global audience. This has made it easier for individuals to share their personal beliefs and to make claims that reach audiences of their followers. However, not all of this shared information is scientifically verified.

Television and radio programs expose us to advertising

Most of us have a TV in our homes and a radio in our cars. When watching or listening to content, we are often exposed to advertising through these platforms, which can use claims to try and convince us to purchase a product. However, visuals such as graphs on TV advertisements and infomercials (which are short programs designed to promote specific products) can sometimes be altered, so that they appear to more strongly support a claim that actually has no scientific basis. The data in Table 8.5 was used to make Figures 8.18 and 8.19. However, it looks completely different in each graph! Which one looks more convincing, if the goal is to try to sell car brand B?

Table 8.5: Car brands, and their acceleration time from 0 to 60 km h^{-1}

Car brand	Acceleration (0–60 km h^{-1}) (s)	Price ($)
A	8.0	30 000
B	6.0	70 000
C	7.0	38 000
D	9.0	27 000
E	8.0	35 000

Social media platforms allow anyone to present information

As stated above, social media has become widely used worldwide over the past few decades. This has meant that there is an increasing ability for anyone to share claims or recommendations for concepts and products that may not actually work. Some of these individuals on social media platforms have such large numbers of followers they are called **influencers**. Advertising companies will often approach influencers

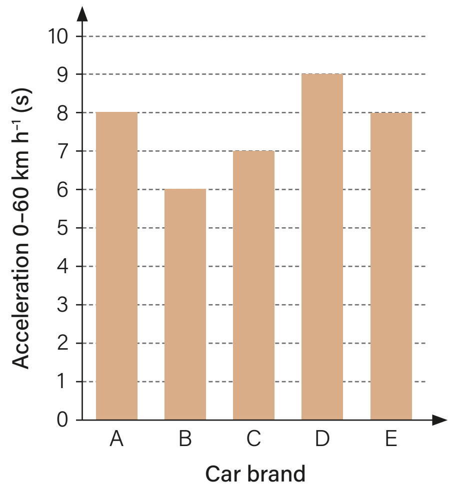


Figure 8.19: This graph presents the data from Table 8.5 in a more scientific way (with an even scale on the *y*-axis that starts at 0). Can you see a difference from Figure 8.18?

and pay them to recommend a product they are selling, such as a cream that treats hair loss or a diet plan. The influencer posts, blogs or records a video promoting the product to their followers. However, many of these companies have not scientifically verified their products or programs through investigations. This means that whatever is being promoted may in fact be based on pseudoscience – with no real evidence to support that it works.

Look out for pseudoscientific claims in the media

The wellness industry is an unregulated industry that often promotes 'lifestyle' and 'diet' programs on social media platforms. However, before taking advice from these industry spokespeople or paid influencers, consider the following:

- The fit- or healthy-looking people who are shown holding a copy of the product or program, or something related to it, may not have used it.
- Check for any qualifications of the people promoting the program. If they have qualifications, they will be well advertised. The absence of any qualifications is telling.
- What are the motives of the company promoting the product or program? Are there links to purchase other products?
- Avoid quick-fix promises. Getting fit and healthy takes time, effort and commitment, so beware of advertised shortcuts or quick fixes.
- Is there some scientific research that supports the program being offered? It is important to see studies or first-hand investigations that support the program.

Many alternative medical processes have little to no scientific support and, as such, are pseudosciences that should be avoided. The wellness industry is unregulated and relies on testimonials and anecdotal evidence, so if a claim sounds too good to be true, then it probably isn't true!

Learning Ladder

Data science 2

1. Propose a claim that a wellness company might make in an advertisement.
2. Describe a social media platform that could contain claims or advertisements based on pseudoscience.
3. Explain why it is easy to access information about products that is not scientifically verified.
4. Discuss three strategies you can use to verify the validity of a program advertised by a health and wellness company.

Analysing data and information *see page 420*

1. Describe a trend you can see in the graph in Figure 8.1.
2. Explain the reasons for the difference in the trends shown in Figures 8.18 and 8.19.
3. Explain a conclusion someone might draw when they see the graph in Figure 8.18 as part of an advertisement on TV for car brand B.
4. Assess the validity of Figures 8.18 and 8.19, in relation to the data in Table 8.5.
5. The TV company advertising car brand B makes a claim that 'its vastly superior acceleration justifies its higher price'. Evaluate this claim, based on your responses to the previous questions.

In context

Some wellness companies claim that certain vitamin supplements will increase brain function and make people smarter. Research this claim and discuss the reasons why advertisements on social media platforms may promote claims like these.

Success criteria

- I can determine instances of pseudoscience in the media and evaluate claims from advertisements for their scientific validity.

8.8 ▸ Features and uses of large datasets

Learning intention

At the end of this lesson, I will be able to understand the features of large datasets or 'big data'.

Key terms

JSON: JavaScript Object Notation; a standard text-based format for storing and transmitting data in web applications

NoSQL: non-relational database system; a database that does not have rigid systems and can store petabytes of data in a format other than tables that enables quick processing of large data volumes and multiple concurrent queries

XML: Extensible Markup Language; allows data to be stored in a shareable manner that can be exchanged between computer systems, websites, databases and third-party applications

Investigation 8.8

How big is big data?, page 600

Content group: Large datasets and scientific argumentation

Large datasets (big data) are extremely large or diverse collections of data that grow exponentially over time. Traditional data management systems cannot cope with the size, rate of growth and variety of data. Specialised systems are needed to use the information in large datasets.

Large datasets can be described by the 5Vs

Big data is often described in terms of the three, four or five Vs, depending on who is defining it:

- **Volume:** Substantial amounts of data can be measured in terabytes (10^{12} bytes) or petabytes (10^{15} bytes). A large volume of data provides a significant amount of information that allows for and requires a comprehensive analysis.
- **Velocity:** Data is generated very quickly and can lose relevance quickly, so it needs to be analysed in close to real time to extract meaningful and current information.
- **Variety:** Large amounts of data can exist in many formats:
  - **Unstructured data**: text, images or video
  - **Semistructured data**: Extensible Markup Language (**XML**) allows data to be stored so that it can be shared and exchanged between computer systems, websites, databases and third-party applications. JavaScript Object Notation (**JSON**) is a standard text-based format usually used to transmit data in web applications.
  - **Structured data:** Non-relational database systems (**NoSQL**) do not have rigid systems and can store petabytes of data in non-tabular form that enables quick processing of large volumes and multiple concurrent queries.
- **Veracity:** Data that is error free is more useful, especially to businesses that rely on it for success and profitability.
- **Value:** High-quality, current and accurate data can be used by organisations to drive business performance and revenue generation.

Figure 8.20: Major retailers use big data for the targeted advertising and sale of products.

Big data is used by companies and organisations

A huge volume of data is generated every minute: more than 3 000 000 emails, 4500 SMS messages, 700 000 WhatsApp messages, 70 000 Google searches, 55 000 Facebook posts and 5500 tweets!

- Major supermarkets invest in big data to predict future consumer trends. Data from check-out scanners is used to focus on long-term supply and sale of all items in the stores. Coles and Woolworths have supplier portals to share information so that they can meet the ever-changing needs of consumers.
- Netflix analyses user behaviour such as daily viewing time, viewing patterns, search history and individual ratings to create ‘top picks for you’. This use of big data is designed to ensure that subscribers keep watching Netflix and results in a retention rate of greater than 90 per cent. The technique used to develop the list involves complex mathematical calculations, as the predictions need to be continually modified as viewing habits change.
- Amazon uses big data from shopping patterns, competitors’ prices and popularity of products to determine their pricing, which can change 2.5 million times a day.
- The Marriott Hotel chain uses big data from local and global economic situations, weather, availability and reservation behaviour, cancellations and major events near individual hotels to adjust their pricing.
- Uber Eats uses its insights as a taxi company and big data about restaurants’ food preparation and delivery times to ensure market leadership.
- Australia’s Commonwealth Scientific and Industrial Research Organisation (CSIRO) analyses big data to accelerate scientific discovery. For example, CSIRO combines and analyses large datasets that contain environmental, weather and geographical information in computer simulations to predict how bushfires might spread.
- The Australian Nuclear Science and Technology Organisation (ANSTO) has several datasets available on its website for analysis. It also provides worksheets for students to complete.

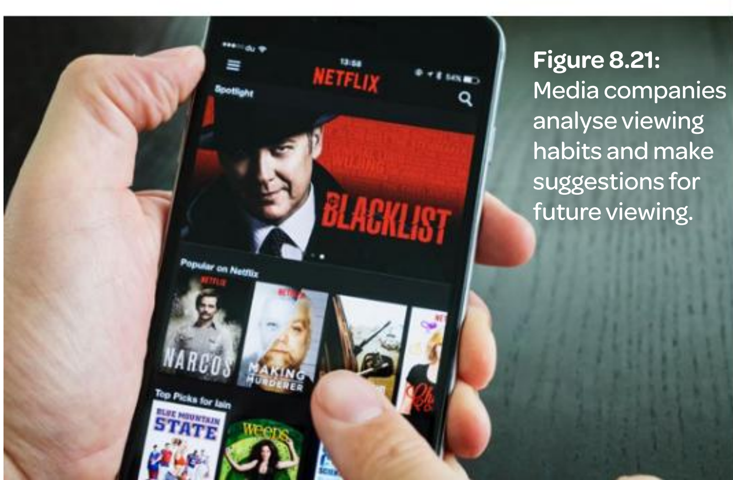


Figure 8.21: Media companies analyse viewing habits and make suggestions for future viewing.

Learning Ladder

Data science 2

1. Identify the five Vs of large datasets.
2. Describe a large dataset and propose how it can be used.
3. Explain why supermarkets might use analyses of large datasets of consumer purchases.
4. Discuss how large datasets can be constructed.
5. Assess the strategy that Netflix uses with its collection and analysis of large data.

Analysing data and information *see page 420*

1. Re-read the first paragraph on this page. Construct a pie chart to reflect the proportions of data types generated each minute. Refer to pages 459–61 of the Science how-to section for assistance in constructing your pie chart.
2. Propose, with justification, why certain types of data are generated more frequently than others. Refer to Question 1 in your response.
3. With reference to your pie chart from Question 1, discuss why a company would prefer to have access to certain types of customer data to inform its business model.
4. Discuss the reliability of the data presented in your pie chart.
5. Evaluate the statement: ‘Large supermarkets want consumers to scan their purchases as a way to collect data.’

In context

Research institutes in Australia, such as CSIRO, also produce and rely on large datasets. Conduct an online search to determine a dataset that CSIRO produces and explain how this dataset helps it in drawing scientific conclusions.

Success criteria

- I can determine the characteristics of large datasets.
- I can describe how this information is used.

8·9 ▸ Analysing large datasets

Learning intention

At the end of this lesson, I will be able to explain how large datasets can be analysed.

Key terms

box-and-whisker plot: a graph that displays numerical data in quartiles; it is a useful way to compare sets of data

descriptive analysis: an analysis of data to identify patterns and relationships

Investigation 8.9

How to use big data, page 601

Content group: Large datasets and scientific argumentation

It is important to ensure the accuracy of big data and the conclusions drawn from that data. Analysis of the data might show a correlation without causality. For example, in summer, there are more people with sunburn and more ice-creams are sold. However, these are not related to each other, so the correlation is not causal. Both are related to the warmer weather, a third variable.

Figure 8.22: There is a correlation between the number of people with sunburn and the number of ice-creams consumed, but there is no causation.

Descriptive analysis helps to identify trends

Although collecting data is useful, it is the interpretation and analysis of the data that allows us to draw conclusions. Once datasets have been collected, they are analysed by computers and scientists. One of the first things to be conducted is a **descriptive analysis** – which looks for trends and patterns, including correlation and causality. (See Section 8.5 to remind yourself about correlation and causality.)

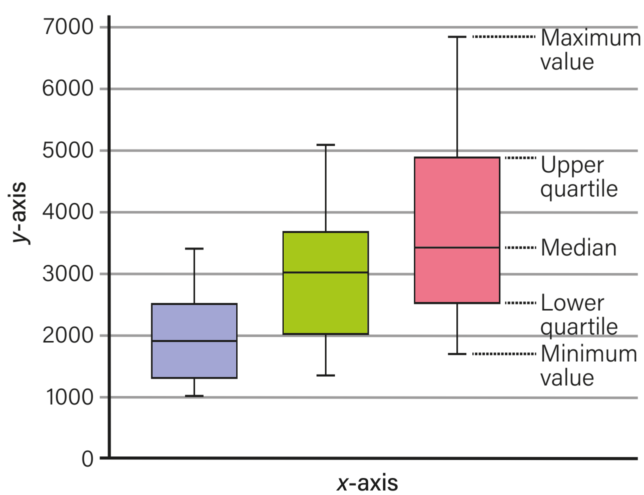


Figure 8.23: Statistics are used when analysing data. This box-and-whisker plot compares three sets of data.

The simplest and most popular tools used in descriptive analysis are the three measures of centre: mean, median and mode. (See the Science how-to section, pages 451–52, for an explanation of these three measures.) A further four measures are:

- frequency, as a count or percentage
- central tendency: mean, median and mode
- dispersion: range and interquartile range
- position: quartiles and percentiles.

Quartiles are displayed well in a **box-and-whisker plot**. Multiple box-and-whisker plots can be used to make comparisons.

It is important that the data being analysed is error free. Such data is valuable for researchers and can influence markets, finances, the environment and other important aspects of society.

Correlation is not necessarily causation

Finding relationships between things can strengthen our understanding and improve our decision-making. When two things change at the same time, there is a correlation. For example, there is a correlation between the position of items on supermarket shelves and the sales of those items. Sales of items displayed at eye level are generally higher than sales of items displayed below or above eye level.

Correlation tells you 'what' has happened, but not 'why' it happened. To find out from big data why something happened (causation), we need to analyse the correlation. For example, in a trial of a new heart medication, scientists might find there is a correlation between participants taking the medication and losing weight and a lowering of their cholesterol levels. The next step is to conduct separate scientific experiments to determine if a causal relationship exists between weight loss and lowered cholesterol levels and, if so, why it exists.

Because of the huge volumes of data that exist, it is possible to find correlations if you look long enough. So, care is needed to ensure a lack of bias. Given enough data, patience and time, correlations are almost inevitable, but many will not be causal.

Causality lets us make predictions

Once analysis of the big data reveals a correlation between two variables, the next step is to determine if the relationship is also causal. An analysis of a big dataset will find many correlations between things, but we need to use the information to find the cause, if there is one. If we know the cause and the interrelationship between the variables, then predictions are possible. Many factors, assumptions and limitations should be considered after a correlation is discovered. Hidden variables, bias issues with the sampling and flaws in interpretation can cloud the inferences made from the correlating data.

Causality can be proven

Once a correlation has been found between two variables to support causality, we need to select a sample and divide it into two groups: the control and the experimental group. For example, it has been found that a particular drug results in hair regrowth (i.e. there is a correlation). The next step would be to administer the cause (the hair regrowth drug) to the experimental group but not to the control group, and compare the results. If there is some overlap between the results in the two groups, then causality is not supported. However, if an analysis of the results indicates that the experimental group has hair regrowth and the control group does not, then causality is proven. However, many other scientists must be able to conduct the same investigation and have the same results for causality to be proven.

Learning Ladder

Data science 2

1. Identify and give an example of correlation.
2. Describe the benefits of analysing collected datasets.
3. Explain how you can have correlation without causation.
4. Discuss the importance of causality when using collected and analysed data.

Analysing data and information *see page 420*

1. The weather forecast is for two weeks of rain. Describe what sales of a particular item may increase.
2. Propose why there may be a correlation between ice-cream sales and sunburn, as stated in Figure 8.22.
3. Big data will always provide many correlations between variables. Explain the importance of determining if causality is present.
4. Assess the importance of collecting data that is accurate and reliable when compiling large datasets, such as those from medial trials for new medications.

In context

Spotify analyses big data to make suggestions to its subscribers. Research the data that Spotify analyses in its decision-making, and explain its importance to the company and the subscribers.

Success criteria

- I can explain how large datasets can be analysed.

8·10 ▸ Univariate and bivariate analysis

Learning intention

At the end of this lesson, I will be able to statistically analyse data using univariate and bivariate data techniques.

Key term

bivariate data analysis: statistical analysis that compares data based on two characteristics or variables

univariate data analysis: statistical analysis that consists of observations of a single characteristic or variable

variable: a factor in an investigation or a model that can be changed, measured or controlled

Investigation 8.10

State of Origin, page 602

Content group: Large datasets and scientific argumentation

Descriptive statistical analysis involves carrying out calculations or constructing graphs to recognise or communicate patterns in data. Calculations may involve measures of centre (mean, mode and median) or measures of spread. A **univariate data analysis** focuses on one single **variable** at a time. A **bivariate data analysis** is used to find a relationship between two variables.

We can analyse team statistics to make claims about the players

Table 8.6 shows the height, weight and age of the NSW Women's Rugby League team members in 2022. It is difficult to make comments about the players by simply looking at the table, but by completing a statistical analysis, we can make some claims about them.

Table 8.6: NSW Women's Rugby League team statistics, 2022

Name	Height (cm)	Weight (kg)	Age (years)
Yasmin Clydsdale	172	70	28
Isabelle Kelly	170	75	26
Teagan Berry	174	68	20
Jessica Sergis	173	72	25
Filomina Hanisi	164	95	21
Millie Boyle	181	83	24
Caitlan Johnston	173	88	22
Keeley Davis	164	68	22
Sam Bremner	165	63	31
Simaima Taufa	153	75	28
Quincy Dodd	165	60	22
Olivia Kernick	181	82	22
Kira Dibb	180	77	25
Shaylee Bent	173	80	22
Sarah Togatuki	157	79	25
Corban Baxter	173	74	28
Emma Tonegato	165	68	27
Hannah Southwell	172	75	23
Tiana Penitani	169	70	27
Rachael Pearson	170	68	29
Kezie Apps	182	82	31
Talei Holmes	170	69	22


Figure 8.24: The NSW Women's Rugby League team, 2022

We can perform a univariate analysis of heights and weights

A univariate analysis examines one variable at a time. So, the mean for each – height, weight and age – can be calculated separately, along with the range for each variable.

Table 8.7 shows the mean (the average of a set of numbers; calculated by dividing the sum of given numbers by the total number of numbers) and the range (the difference between the largest and smallest value in a dataset) of the three variables for the NSW Women's Rugby League team in 2022.

Table 8.7: The mean and range of height, weight and age of the NSW Women's Rugby League team, 2022

Value	Height (cm)	Weight (kg)	Age (years)
Mean	170	75	26
Range	29	35	11

From these calculations, we can comment on the height, weight and age of a player. Then we can compare them to the mean values. For example, Isabelle Kelly is 170 cm, 75 kg and 26 years old, so she could be described as the 'average' NSW Women's Rugby League player from the 2022 team, as her height, weight and age are the same as the mean values obtained. Each variable (height, weight and age) represents an individual univariate analysis.

We can perform a bivariate analysis of heights and weights

Figure 8.26 is a scatter plot with the players' heights on the horizontal (x) axis and weights on the vertical (y) axis. Each point represents a player's height and weight. This is a bivariate analysis, as it is looking for a relationship between two variables.

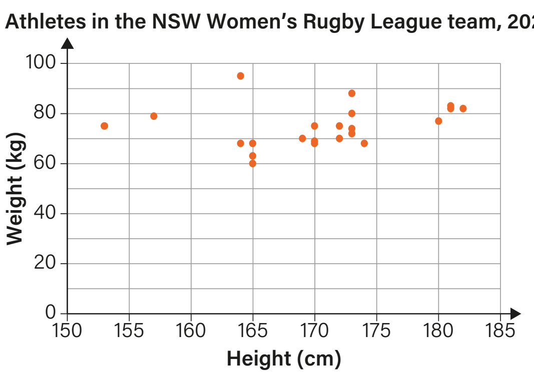


Figure 8.26: A scatter plot of heights and weights of NSW Women's Rugby League team, 2022

Figure 8.25: Isabelle Kelly is an 'average' NSW Women's Rugby League player based on her height, weight and age.

Learning Ladder

Data science 2

1. Identify one method of univariate data analysis.
2. Describe the difference between univariate and bivariate data.
3. The heights and weights of the players are plotted on a scatter plot in Figure 8.26. Explain any correlation that may be present.
4. Discuss the reasons for any correlation you identified in Question 3.

Analysing data and information *see page 420*

1. Describe the trend if any in the height vs weight scatter plot in Figure 8.26.
2. Explain if the calculation of mean height and weight assists with locating a trend.
3. Use the data in Table 8.6 to construct a scatter plot comparing height and age. What conclusion can you draw from the scatter plot?
4. Assess the validity of your answer to Question 3.
5. A statement is made that older players are taller. Evaluate the data in the table and determine the accuracy, reliability and validity of the statement.

In context

The Matildas soccer team performed well at the 2023 FIFA Women's World Cup. Research the team statistics for height, weight and age and compare them to the NSW Women's Rugby League team statistics. Conduct relevant data analysis to determine if there is a difference in the physical make-up of the two teams. Propose reasons for any differences you find.

Success criteria

- I can use both univariate and bivariate data analysis techniques to make conclusions about data.

8·11 ▸ Causal and correlational relationships

Learning intention

At the end of this lesson, I will be able to determine if a correlation is causal.

Key terms

Hawthorne effect: the fact that people change their behaviour if they know they are being observed

Investigation 8.11

Heads and tails, page 604

Content group: Large datasets and scientific argumentation

▲ **Figure 8.27:** Exercise enhances our physical, mental and emotional wellbeing.

We have seen above that relationships between data can be correlational or causal. It is important to be able to use this understanding to analyse data, so that causal relationships can be correctly inferred. To do this, two variables must be carefully examined in isolation, using a scientific investigation.

Many relationships show correlation without causality

The **Hawthorne effect** is a classic example of correlation without causality. In the early 1900s, a series of experiments took place at the Hawthorne factory in the United States. Researchers made changes in the factory environment to see if it would affect productivity. They changed the lighting, moved the workstations, and made other changes, and then measured productivity. The factory managers were pleased with the increase in productivity, which they correlated with the changes to the factory. However, as soon as the researchers left, productivity declined. It was the workers' knowledge that they were being observed as part of the experiment being conducted that prompted the increase in productivity, not the changes made in the factory.

Here are some other examples of correlation without causality.

- Data shows that per capita cheese consumption is correlated with the number of deaths caused by bedsheet entanglement. However, there is no logical or causal connection between these variables. The correlation is coincidental and serves as a classic example of how unrelated variables can appear to be connected purely by chance.
- People who drink more than four cups of tea a day have lower rates of skin cancer. This is a positive correlation but the reason is not causal. People who drink more than four cups of tea a day may be more likely to work inside and have less exposure to sunlight. But it is the staying out of sunlight, not the tea drinking, that causes the lower incidence of skin cancer in that group.
- At a fast-food restaurant, the cost of burgers increases, and so does the cost of soft drinks. It might appear that the increase in the cost of the burgers causes the increase in the cost of the soft drinks. However, both are probably increased independently of each other due to rising business expenses.
- Some humorous charts show that as the number of sea pirates has decreased over centuries, global temperatures have increased. While the data might show a correlation, there is no causal link between

Figure 8.28: A previous scientific study suggested that there was a causal link between vaccinations and autism. This study has since been discredited. Vaccinations save lives, but do not have a causal link to autism.

these variables. The apparent relationship is purely coincidental, and is often used to illustrate how unrelated variables can seem connected in data.

There is no causal relationship between vaccinations and autism

In the 1970s, a pseudoscientific unproved theory linked the measles, mumps and rubella (MMR) vaccine with autism. By the late 1990s, scientific research had proved that there was no causal link between the MMR vaccine and autism, and that vaccinations in general are not associated with the development of autism. However, the damage was done, vaccination levels decreased, and cases of measles increased significantly among the unvaccinated. Vaccine misinformation re-emerged during the COVID-19 pandemic. Some people thought that the vaccines were unsafe due to the short development time, and that they affected fertility, which was scientifically proven to be false.

Some relationships show correlation with causality

- Smoking causes an increase in lung cancer. This is a correlation that is causal. Smoking is the cause, and lung cancer is the effect.
- Regular exercise leads to an improvement in health. Exercise is the cause, and improved physical health is the effect.
- Receiving vaccinations reduces the incidence of the diseases they are designed to prevent. The vaccination is the cause, and the reduced incidence of disease is the effect.
- Exposure to the Sun increases vitamin D levels. Being exposed to the Sun is the cause, and the effect is an increase in vitamin D.

Learning Ladder

Data science 2

1. Identify a causal relationship stated in this section.
2. Describe an example of a correlation that is not a causal link between two variables.
3. Explain how you determined that the answer to Question 2 is not a causal link.
4. ‘In summer, ice-cream sales and shark attacks both increase. Therefore, sharks must be more attracted to swimmers who have ingested ice-creams.’ Assess the validity of this claim, and determine whether the link between ice-cream sales and shark attacks is correlational or a causal link.

Analysing data and information

see page 420

1. Describe a trend in burger prices if the cost of beef increases by $1.50 per kilogram.
2. Explain the implications for children’s health if vaccination rates decrease.
3. ‘The weather is cold, and the sales of puffer jackets increase.’ Discuss the correlation and causality of this statement.
4. At the end of winter, all remaining puffer jackets in a store had their prices reduced by 75 per cent. Sales of jackets over the next three weeks were higher than they had been across all of winter. Assess the conclusion drawn by the store manager that ‘more people wear puffer jackets in spring than in winter’ for its validity, and determine if this is a correlational or causal link.

In context

The COVID-19 pandemic had a huge impact on Australia and the rest of the world. Vaccines were developed rapidly and saved many lives. There was a clear correlation between vaccination rates and a reduction in death rates. Conduct some research into COVID-19 vaccination rates and lower death rates that supports the correlation being causal.

Success criteria

- I can determine whether a correlation is causal.

8.12 ▸ Using statistical analysis to validate findings

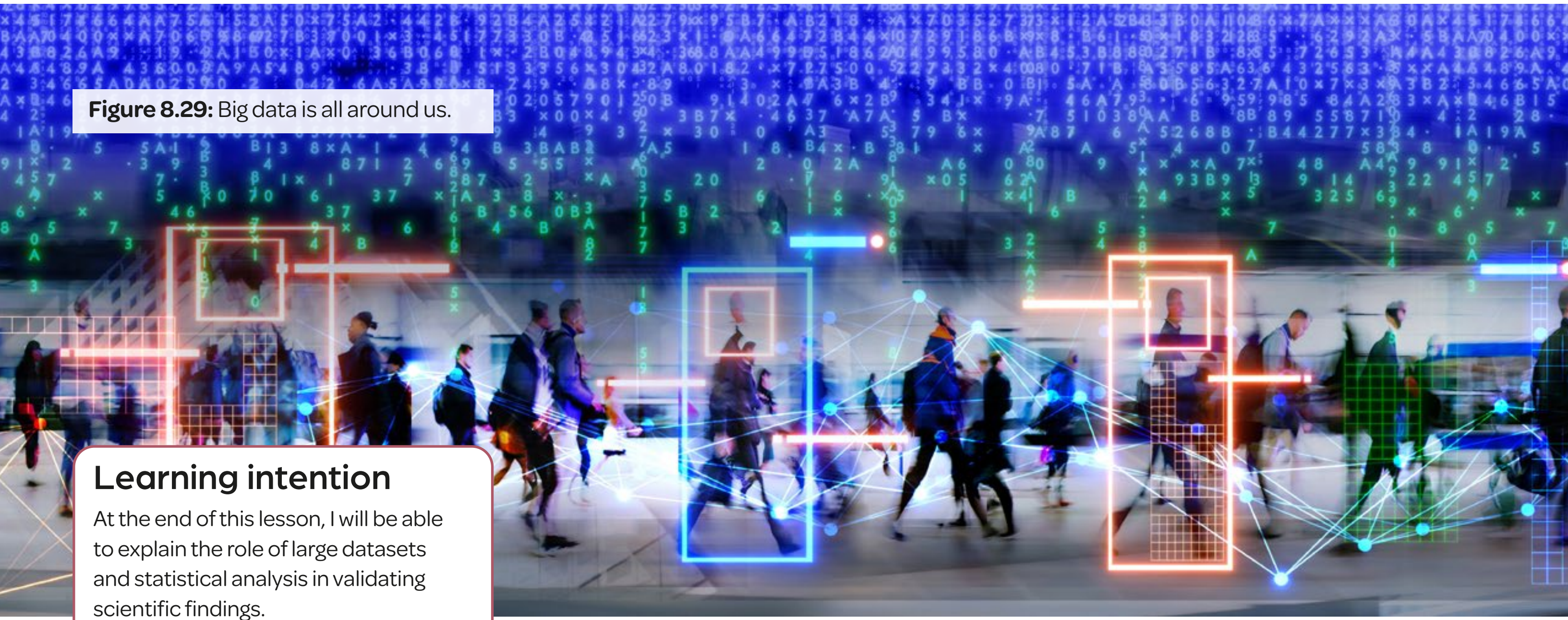


Figure 8.29: Big data is all around us.

Learning intention

At the end of this lesson, I will be able to explain the role of large datasets and statistical analysis in validating scientific findings.

Key terms

data error: inaccurate data

demographic: a particular set of a population (e.g. age, sex, occupation)

sensitive data: confidential personal, business or classified information

Investigation 8.12

What is your temperament?, page 606

Content group: Large datasets and scientific argumentation

Figure 8.30: Streaming services use big data to analyse subscribers' viewing habits.

Big data can reveal patterns that are not discernible in small datasets because of the amount of information available. However, big data can introduce statistical challenges such as scale, spurious correlation and measurement errors.

Large datasets help to validate scientific findings

Scientists who conduct investigations multiple times with large sample sizes are able to compile large datasets. These datasets, when applied, can help to validate scientific findings. Larger amounts of data increase scientists' confidence that the relationship between two variables is causal, rather than correlational.

An example of this was seen in Gregor Mendel's pea plant investigations. Mendel collated results from data he collected from over 30 000 pea plants across his investigations. Mendelian ratios are scientifically accepted to this day as valid, based on the accuracy of Mendel's methods and the reliability afforded by his sample size.

Today, a lot of large datasets are collated as digital big data. This requires a number of considerations. These are discussed below.

Big data provides benefits

The benefits of big data are wide-ranging, from improving health care to creating better business models. Some of its benefits are:

- improved risk management through improved risk detection

- better decision-making insights by finding patterns and causal correlations
- increased innovation and intelligence as a result of real-time data
- more efficient business operations from the analysis of data.

Big data has challenges

The challenges when collecting, managing and acting on big data include:

- a shortage of people with data analysis skills
- the sheer volume of data to be managed
- data accuracy: just because there is lots of data does not make it accurate
- the amount of **sensitive data** that must be protected
- data security
- ensuring that any conclusions drawn from the analysis of big data are valid and reliable.

Data validation ensures the quality and accuracy of data

Checks are needed to ensure the consistency of data because inconsistent data may lead to **data errors**. Many large datasets are collected and stored with minimal supervision. Structured and semistructured data are easier to validate. Unstructured data needs more careful analysis to ensure usefulness.

Several checks can be used to validate data:

- Check that the correct data type (quantitative or qualitative) is analysed to yield numerical or non-numerical outputs as required.
- If possible, check responses against known values. For example, if someone inputs their phone number, the company collecting the data can check that the area code for the number matches the address given.
- Make sure that numeric fields have an accepted range of values. For example, if an age is required, parameters should be set to deliver the desired data. If data is to be formatted in a particular way, then the formatting must be prescribed; for example, date of birth: DD/MM/YYYY.
- Have a unique ID for the data, such as an email address, a person's name and date of birth, or a unique number generated by the system.

For example, if a streaming service collects data on song selection but does not cross-reference that against an age **demographic** or a region, then the data would not be valid for a particular purpose. It is not possible to market to a particular demographic without data correlated to that demographic. These checks help to make the data useful and valid when analysed.

Learning Ladder

Data science 2

1. Identify some challenges of big data.
2. Describe the challenges associated with big data analysis.
3. Explain the benefits associated with big data analysis.
4. Discuss the features of large datasets.
5. Assess the value of using large datasets to make decisions regarding real-world problems.

Problem-solving

see page 425

1. A problem associated with the analysis of big data is the size of the datasets. Propose a solution to this problem.
2. Information is collected on the choice of pizza by consumers in different postcodes. Explain how this information might be used to position pizza shops and to plan menus.
3. More data leads to more correlations. Explain how you could determine which correlations have causality as the number of correlations between pieces of data increases.
4. Assess the strategies used to solve the problem of gaining data that is invalid.
5. Discuss the benefits and challenges of using big data and use these to evaluate the claim: 'Big data is the only data that is relevant to science.'

In context

Identify three correlations that may appear in the analysis of big data collected about people's choices of petrol or electric cars. Use secondary sources to determine if any of the correlations you have identified are causal links.

Success criteria

- I can explain how large datasets are used to ensure that scientific conclusions are valid.

8·13 ▸ Data science 2 in context

Learning intention

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

- use data to make evidence-based decisions about familiar situations
- assess the implications of these decisions.

Key terms

evidence-based: a strategy or conclusion that is drawn from information taken from data

implication: the effect a decision will have on other factors relating to it

Content group: Data science 2 in context

Technology makes data available all around us. We can use data to make many different decisions, which can in turn influence us and those around us.

Data can be used to make decisions

Every morning, when we get out of bed, we often have considered and used data to make decisions without even realising it! When we see data, or compilations of data, we can analyse it for trends, correlations and causality. The outcome of these helps us to make decisions relating to the collected and analysed data.

For example, most mornings, many people look at the weather forecast before planning what to wear. Weather apps are run on models generated from complex, large datasets and directly influence the decisions we make.

Another example is wearable trackers, such as smartwatches that can track our step count and heart rates. This daily data is fed back to an app, which generates graphs that show us trends over time. Someone who has seen their step count trending downwards may decide to park further away from their workplace, in order to improve their fitness and increase their number of daily steps. Another person might decide to book a doctor's appointment if their heart rate data suddenly changes significantly.

Decisions can have external implications

It is important to consider the **implications** of our choices when making **evidence-based** decisions using data. Incorrect decisions about our clothing or step count may not seem important, but other data-driven decisions can have massive impacts. For example, an incorrect decision by an investment company could result in large money losses for many clients.

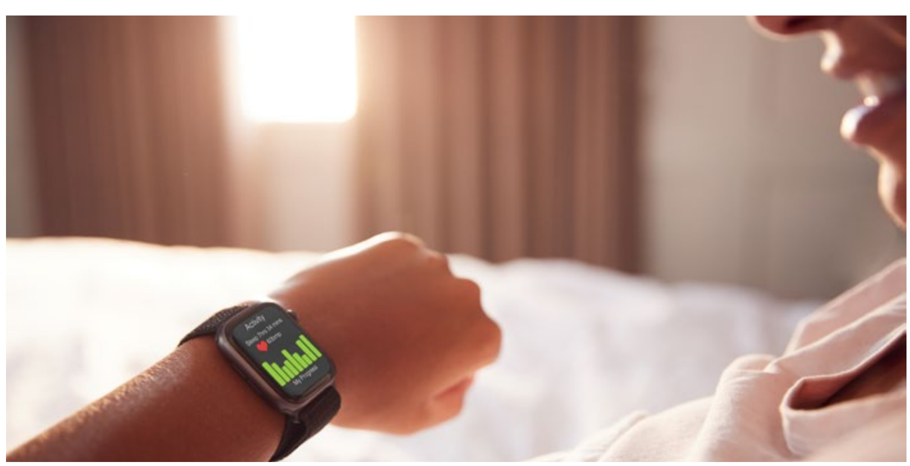


Figure 8.31: Smartwatches can provide us with data about our steps and heart rate, which we can use to make decisions about our daily activity and, possibly, health care.

Figure 8.32: If financial institutions make poor investment decisions, it can have negative implications for all their clients.

The implications of decisions need to be assessed

To help minimise the implications of decisions, they need to be carefully assessed. This is done by:

- considering the decision that is being made
- deciding on the benefits of the decision
- identifying any limitations of the decision
- making a judgement on whether to continue with the decision as originally planned.

For example, if we use the weather forecast to plan what to wear, we would do the following:

- Consider the decision: 'It is going to be 23 °C today, and cloudy, so I'm going to wear shorts and a T-shirt.'
- Decide on the benefits of the decision: 'I won't get too hot, and I'm not likely to get sunburnt, because I'll be inside a lot.'
- Identify limitations with the decision: 'When it's cloudy, it can also get windy, and that can make it feel colder. I might be cold if I don't have a jumper to wear.'
- Make a judgement on whether to continue as planned: 'I'm still going to wear my shorts and T-shirt, but I'll also put a jumper in my bag, in case it gets windy and cooler. That way I have a way to stay warm.'

Assessing the implications of decisions ensures that we know we are using the data the best way we possibly can.

Table 8.8: Most smartwatches and smartphones contain step trackers that will show a person's total daily steps.

Day	Number of steps
Monday	9504
Tuesday	12 350
Wednesday	9842
Thursday	5733
Friday	9929
Saturday	12 426
Sunday	9514

Learning Ladder

Data science 2

1. Identify a piece of data you use every day.
2. Describe how this piece of data may influence a decision you make during the day.
3. Explain any other factors that may influence the decision you make.
4. Discuss the benefits and limitations of making this decision.
5. Assess the use of this data, and any implications your decision might have on you or those around you.

Communicating

see page 429

1. Propose a way to communicate to a friend a limitation of a decision they had made about what to wear that day.
2. Construct a digital graph that could represent the data shown in Table 8.8. More information on constructing graphs is available in the Science how-to section on pages 457–61.
3. Construct a table that shows a variety of different weather conditions and the outfits you would wear in each condition.
4. Explain how you could use the table you constructed in Question 3 to help communicate information to young students who were only just learning to make data-informed decisions.

Success criteria

- I can make evidence-based decisions using data.
- I can assess the implications of these decisions for myself and others.

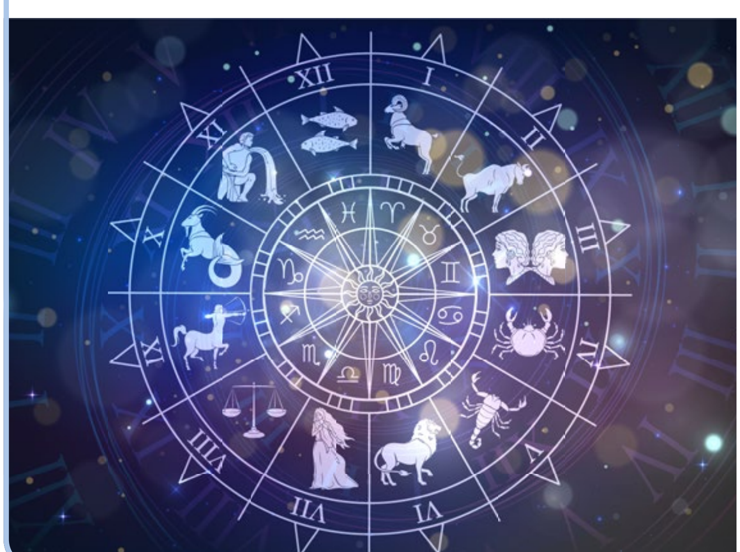
► Data science 2 summary

Investigating questions and claims

- Investigable questions have a defined independent and dependent variable and can be examined using available resources.
- Scientific knowledge and claims are reviewed and tested by multiple scientists to ensure that they are current, credible and consistently achievable.
- Criteria used to assess the validity and reliability of online information include audience, authority, accuracy, objectivity, currency and usability.
- Claims that can be tested can be formed into scientific questions, such as: 'Does the sugar content of a drink impact on tooth decay?'
- Data that is collected from a first-hand investigation and is also supported by valid secondary sources of information increases our confidence in scientific findings.
- Data that remains consistent when repeated under the same conditions increases our confidence in findings from first-hand investigations.
- Written arguments can be constructed to support claims by: identifying the claim, gathering evidence, analysing the evidence, using reasoning to interpret the evidence, and constructing an argument from your findings.

Pseudoscience

- Scientific claims have been continually researched and are backed up by evidence-based data from investigations. Pseudoscientific claims are alternative explanations of phenomena that are not supported by scientifically compiled evidence.



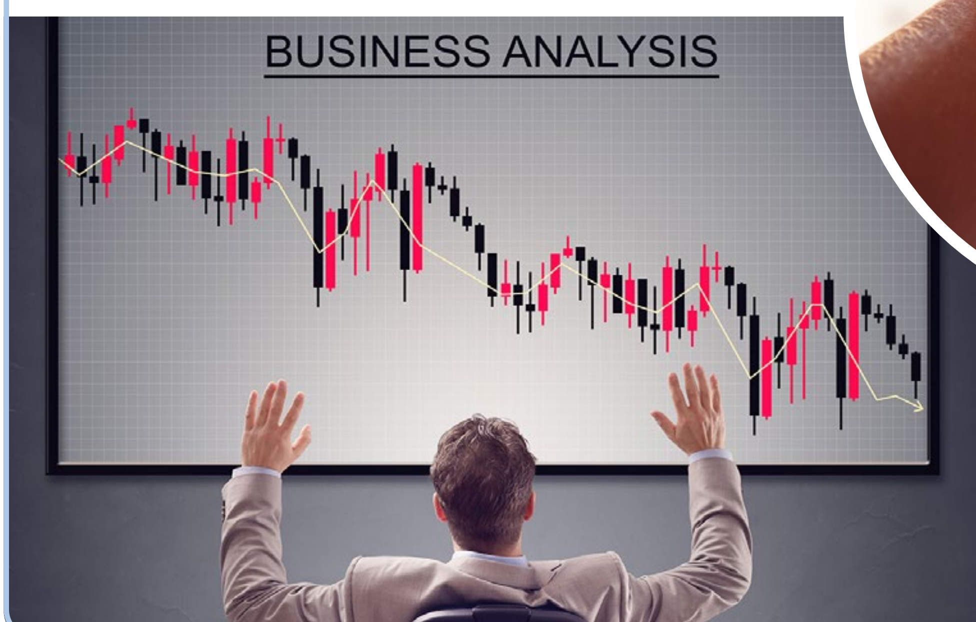
- Pseudoscientific claims include:
  - Flat-Earth theory: the claim that Earth is flat when scientific evidence proves that it is spherical.
  - Astrology: the notion that the position of the celestial bodies influences personality and behaviour.
  - Feng shui: the idea that the organisation of energy flows in a physical space can bring balance and success in life.
- Media representation is not necessarily accurate or scientific. Ideas, theories and representations of content that appear to be scientific may have no scientific validity. This occurs across all branches of media but is especially concerning in social media when propagated by influencers with large numbers of followers.
- First- and second-hand investigations can be conducted to determine whether or not a claim is pseudoscientific.

Large datasets and scientific argumentation

- Big data can be described using five Vs: volume, velocity, variety, veracity and value.
- Large computers collect, compile and analyse big datasets, which can then be used, for example, by streaming services to make viewing suggestions, or by supermarkets to determine which products to advertise more.
- Descriptive analysis of data helps us to identify patterns and trends. These are called correlations.
- Investigations must be conducted into correlations, to see if there is causality: Is the relationship simply random, or is one factor directly responsible for the change in another factor?
- Determining causality is beneficial, as it allows us to make predictions about future trends and patterns.
- A univariate analysis is an analysis of a singular factor or characteristic, such as height or weight or age. We can compile mean data on any single one of these factors.
- Bivariate analysis is analysis of two characteristics to determine if they are linked – e.g. graphing height and age, to see if there is a correlation between them.
- Large datasets are beneficial in validating scientific findings, as they allow scientists to see large amounts of supporting evidence and to clearly identify outliers. The larger the amount of data that supports the idea, the more scientifically valid it is.

Data science 2 in context

- Data can be used to inform everyday decisions that we make – e.g. weather data, which can influence how we dress each day.
- If financial institutions make poor investment decisions, it can have negative implications for all their clients.



- Step trackers on smartwatches and smartphones that show a person's total daily steps provide data that can be used in making decisions.

Masterclass

Steps in progression		1	2
Content	Data science 2	Identify two scientific claims made about the shape of Earth.	Describe how the data collected from satellites could be used to support the idea that Earth is round.
Processes	Analysing data and information	Describe any trends you can see in the data in Table 8.9.	Propose a reason for the trend(s) you identified in step 1. Explain your reasoning.
	Problem-solving	The claim 'Earth is round' requires supporting evidence. Propose one piece of supporting evidence that could be used to help verify this claim.	Explain the link between the height of the torch and the phenomenon of the shape of Earth in the 'flat Earth' experiment described below.
	Communicating	Propose a way that you could present three pieces of evidence that support a claim about Earth's shape.	Use Google Sheets, Excel or another software application to construct an appropriate digital graph from the data in Table 8.9.

Data helps to verify the shape of Earth

As we explored in Sections 8.6 and 8.7, 'pseudoscience' refers to claims that have not been developed using scientifically acceptable approaches. An example of this is flat-Earth theory – the idea that Earth is flat rather than round. Some flat-Earth theorists decided to conduct a first-hand investigation to provide supporting evidence for their claim. However, the investigation disproved their theory! The group shone a torch through a hole that was 5 m off the ground (see Figure 8.33). However, the light from the torch could not be seen through an identical hole 15 m away from them. The torch had to be raised an additional 2 m for the light to be seen, on account of the curved surface of the Earth!

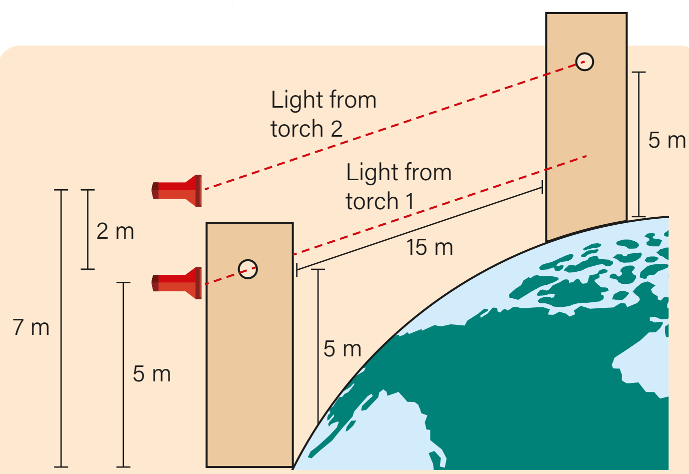


Figure 8.33: An experiment designed to illustrate that Earth is flat was foiled by the curvature of the Earth, which proved our planet is round.

We know the Earth is round, and scientists utilise data and perform calculations based on this verified scientific fact to launch satellites. In turn, these satellites provide data and pictures of the spherical Earth they orbit around. Data from first-hand investigations and technologies is vital to ensure that claims can be validated, before they are accepted by the scientific community.

Demonstrate your understanding

3	4	5	
Explain how qualitative observational data can help to support the idea of a round Earth.	While orbiting Earth, satellites can provide us with a lot of data, which can be held in datasets. Use secondary research to identify and discuss three ways that data from satellites is used in Australia.	Assess the use of data from flat-Earth theorists in verifying their claim that Earth is flat.	
Draw a conclusion about the shape of Earth, based on the data and information provided.	Assess the accuracy, reliability and validity of the investigation conducted by the flat-Earth theorists.	Evaluate the evidence collected by the flat-Earth supporters, and explain why it did not support their claim.	Science how-to p. 420
Figure 8.34 shows that ships appear to sink as they reach the horizon. This observation is questioned by the flat-Earth community as to whether it constitutes evidence that Earth is round. Propose how you could use a model of a boat as qualitative evidence that Earth is round.	Assess the strategies you used to solve the problem posed in step 3. Were they scientifically valid? Why or why not?	Evaluate the claim 'Earth must be flat' based on the evidence you have read and collected from secondary sources.	Science how-to p. 425
Construct your identified presentation from step 1, making sure to include text, visuals, diagrams and data as needed.	Discuss the features of your presentation that make it a convincing argument you could present to someone who did not share your viewpoint on Earth's shape.	Use secondary research to identify and evaluate three findings within the scientific community that provide supporting evidence that Earth is round.	Science how-to p. 429

Figure 8.34: Ships that appear to sink as they disappear over the horizon provide qualitative evidence supporting the claim that Earth is round.

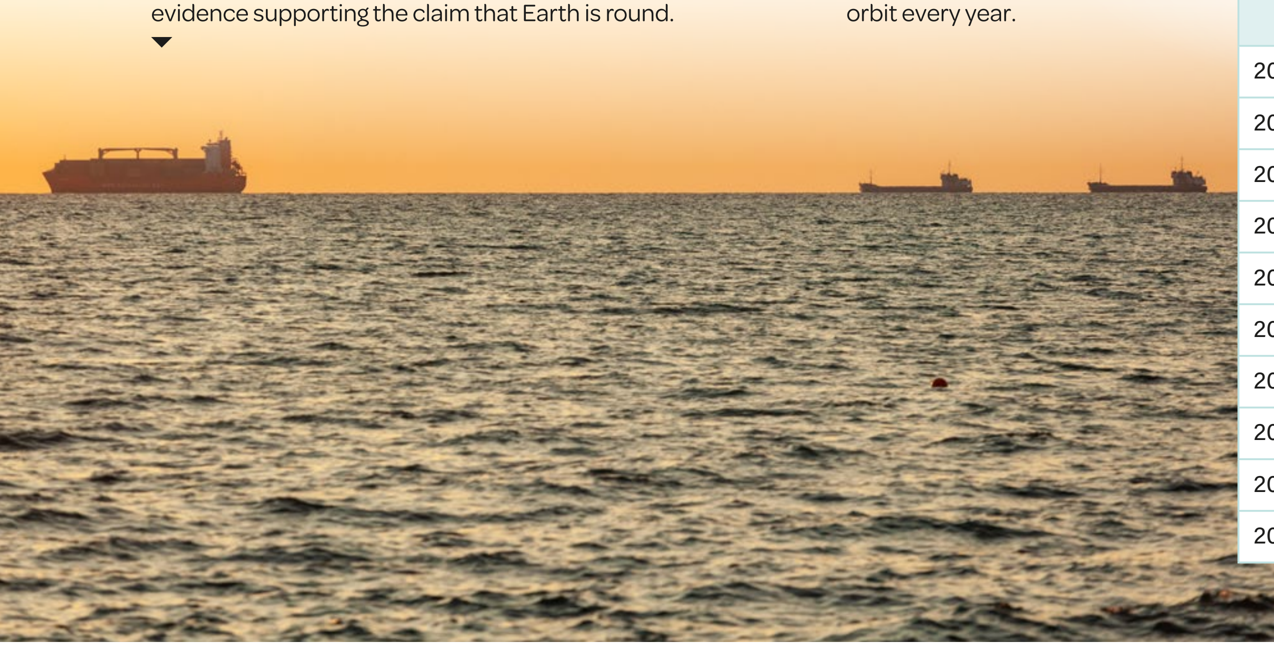


Table 8.9: Increasing numbers of satellites are launched into orbit every year.

Year	Total number of objects launched into orbit
2014	241
2015	222
2016	221
2017	456
2018	454
2019	586
2020	1274
2021	1813
2022	2478
2023	2664

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 Key verbs and response modelling

Key verbs are the instruction words in a question. They tell you the approach to use when you answer.

The key verbs 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 increase in heat of a light bulb when it is in use.
Sample response	*Light bulbs transform electrical energy into light energy so that we can see. However, this energy transformation is not 100 per cent efficient, as some of the energy is transformed into heat and sound energy. So, when light bulbs are on, we can feel that they have heated up as a result of the inefficient energy transformations.*

Analyse	
Explanation	Identify components and the relationship between them. Draw out and relate implications.
Sample question	Analyse the link between Darwin's finches and the theory of evolution by natural selection.
Sample response	*The finches of the Galapagos Islands provide us with supporting evidence for the theory of evolution by natural selection.* *Finches from South America migrated to the Galapagos Islands, settling on different islands that had different environments and food supplies.* *On each island, the main food supply meant that particular beak shapes were a favourable trait for sourcing and consuming the food supply; for example, sharp beaks were favourable for breaking open hard seeds.* *This meant that the finches with these favourable beak shapes were more likely to survive, reproduce and pass on their genetics for the beak shape to the next generation of the population. Over time, this resulted in populations of finches that were distinct species of different sizes and shapes on each of the islands.* *These differences provide supporting evidence for the theory of evolution by natural selection, as the finches evolved over generations to suit the island environment they lived in.*

Apply	
Explanation	Use, utilise, employ in a particular situation.
Sample question	Apply your understanding of chemical reactions to categorise the following reactions: **1** $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ **2** $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$
Sample response	*Chemical reactions can be categorised by their reactants and products.* *In reaction 1, an acid and a metal are reacting to form a metal salt and hydrogen gas, making it an acid–metal reaction.* *In reaction 2, methane gas is reacting in the presence of oxygen, producing carbon dioxide and water as steam, making it a complete combustion reaction.*

Assess	
Explanation	Make a judgement of value, quality, outcomes, results or size.
Sample question	Assess the effectiveness of using solar energy to reduce household power costs.
Sample response	*Solar energy is energy from sunlight that is converted by panels into usable electrical energy.* *Advantages:* • *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.* *Disadvantages:* • *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.* *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.*

Calculate

Explanation	Ascertain/determine from given facts, figures or information.
Sample question	Conduct a first-hand investigation to determine the effect of string length on the time it takes a pendulum to swing. Calculate the average length of time for a 60 cm string length.
Sample response	*The pendulum took 1.5 seconds in trial 1, 1.6 seconds in trial 2, and 1.6 seconds in trial 3. This means the average time taken is:* $\frac{(1.5 + 1.6 + 1.6)}{3} = 1.57$ *seconds.*

Compare

Explanation	Show how things are similar or different.
Sample question	Compare the use of renewable and non-renewable resources in energy production.
Sample response	*Similarities:* • *Renewable and non-renewable resources can both be transformed into electrical energy.* • *Renewable and non-renewable energy both rely on the construction of infrastructure (e.g. wind turbines and power stations) in order to produce electrical energy.* *Differences:* • *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. Put together items or arguments.
Sample question	Construct a poster, diagram or presentation to show your understanding of the electromagnetic spectrum.
Sample response	Different versions of responses to this question are shown in 'Presenting scientific information' on pages 436–41.

Figure S1.1: Solar farms help to reduce the amount of non-renewable resources that are needed for electrical energy production.

Define	
Explanation	State the meaning and identify essential qualities.
Sample question	Define the term 'pathogen'.
Sample response	*A pathogen is an agent that can cause infectious disease in a host.*

Describe	
Explanation	Provide characteristics and features.
Sample question	Describe how a diatomic molecule of chlorine is held together.
Sample response	*Chlorine atoms contain seven electrons in their valence shell. To bond together, two atoms of chlorine each 'share' one of their valence electrons, allowing them to covalently bond as a diatomic molecule, with each chlorine atom now satisfying the octet rule with a full valence shell.*

Discuss	
Explanation	Identify issues and provide points for and/or against.
Sample question	Discuss the use of non-renewable energy such as coal for large-scale electrical energy generation.
Sample response	*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.* *Advantages:* • *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.* *Disadvantages:* • *Burning coal releases large amounts of carbon dioxide into the environment, 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	Recognise or note/indicate as being distinct or different from. Note differences between.
Sample question	Distinguish between infectious and non-infectious diseases.
Sample response	*Infectious diseases are diseases that are caused by a pathogen and can be transmitted from one host to another. Non-infectious diseases, however, are caused by chemicals, the environment or genetics, and cannot be transmitted from one individual to another.*

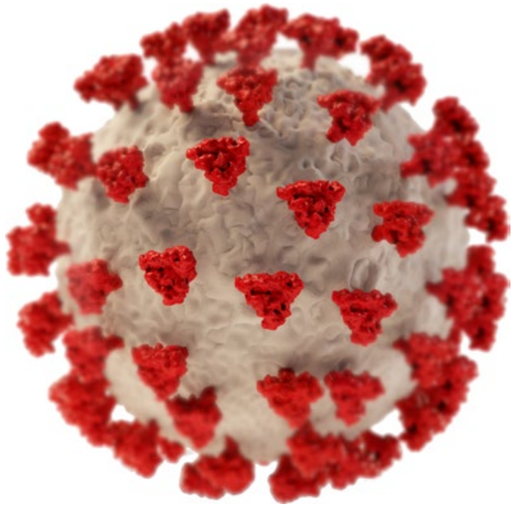


Figure S1.2: Infectious diseases are transmitted by pathogens, such as this COVID-19 virus.

Evaluate	
Explanation	Make a judgement based on criteria. Determine the value of.
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	*Wind energy is a renewable form of electricity that uses turbines to transform kinetic energy into electrical energy.* *Advantages:* • *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.* *Disadvantages:* • *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.* *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 reduce the amount of pollution in the atmosphere.*

Explain	
Explanation	Relate cause and effect. Make the relationships between things evident. Provide why and/or how.
Sample question	Explain how increasing the mass of a car can change its impact force in a collision if its acceleration remains constant.
Sample response	*Newton's second law of motion states that 'the acceleration of an object is proportional to its net force and inversely proportional to its mass'. This means that as the mass of the car gets bigger, its acceleration gets smaller. So, if the acceleration was kept the same, this would mean that the force of the car colliding with another object would increase as its mass increased.*

Extrapolate	
Explanation	Infer from what is known.
Sample question	Looking at the graph, extrapolate what will happen when the temperature of the water is 70 °C.
Sample response	*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.*

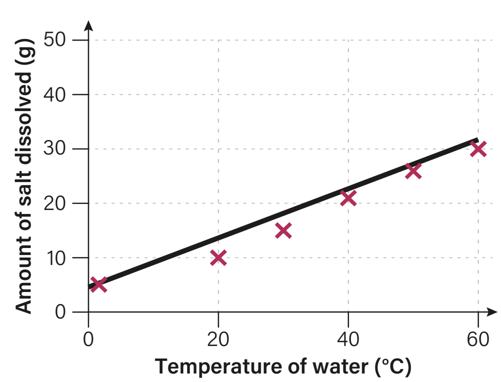


Figure S1.3: A graph showing how much salt is dissolved as water temperature increases.

Identify

Explanation	Recognise and name.
Sample question	Identify the type of chemical bond in a molecule of sodium chloride (NaCl).
Sample response	*Ionic bond.*

Investigate

Explanation	Plan, inquire into and draw conclusions about.
Sample question	n/a
Sample response	Investigating is covered in the 'Writing investigation reports' section on pages 434–36.

Justify

Explanation	Support an argument or conclusion.
Sample question	Justify the use of energy-efficient appliances.
Sample response	*We should use energy-efficient appliances whenever possible to reduce the amount of electrical energy we use in our homes on a daily basis. Reducing the amount of energy we consume is beneficial, because it reduces the amount of fossil fuels we require in order to produce electrical energy. It also means that we consume fewer kilowatts, which reduces our power bills!*

Figure S1.4: Using energy-efficient appliances helps the environment and saves you money on your power bill!

Outline

Explanation	Sketch in general terms; indicate the main features of.
Sample question	Outline the law of conservation of energy.
Sample response	*The law of conservation of energy states that energy cannot be created or destroyed; it can only be transferred or transformed.*

Figure S1.5: We can predict the impact of vaccination on disease rates.

Predict	
Explanation	Suggest what may happen based on available information.
Sample question	Predict the effect of vaccination levels on the occurrence of chickenpox cases.
Sample response	*If the number of vaccinated individuals increases, then the number of chickenpox cases will decrease, because more people will be immune to the disease.*

Propose	
Explanation	Put forward (for example, a point of view, idea, argument, suggestion) for consideration or action.
Sample question	Propose a reason for wearing safety glasses when working with sodium hydroxide.
Sample response	*Sodium hydroxide is a basic solution that is caustic and can cause burns to our skin and eyes. Wearing safety glasses prevents the solution from contacting our eyes and causing damage or blindness.*

Recall	
Explanation	Present remembered ideas, facts or experiences.
Sample question	Recall the rules for naming simple inorganic ionic compounds.
Sample response	*The rules for naming ionic compounds are:* **1** *Write the cation first.* **2** *Write the anion second.* *Replace the end of the anion with the suffix 'ide'.*

Summarise	
Explanation	Express, concisely, the relevant details.
Sample question	Summarise the methods of infectious disease transmission.
Sample response	*Infectious diseases can be transmitted through direct transmission, where the pathogen is passed directly from one person to the next through actions like shaking hands or kissing, or through indirect transmission, where the pathogen can be transmitted by an intermediary such as air, water or animal vectors.*

S2 Working scientifically

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

correlation: a relationship between two factors or variables that shows them changing together, in either the same or opposite way

data: a collection of information gathered through observations, measurements, study 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 that 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

relationship: a link between two factors

reliability: when repeated trials provide consistently similar results

trend (data): when data moves in a general direction, usually up or down

validity: when an investigation measures what it is meant to measure

variable: a factor in an investigation or a model that can be changed, measured or controlled

Science has its own processes that help us to question and test how the world around us works. Scientists use these processes to conduct investigations and test their ideas. Working scientifically allows you to collect information and test your ideas to discover how different parts of the world work.

Figure S2.1: Working scientifically

Understanding working scientifically

Working scientifically requires following eight fundamental processes:

1 observing
2 questioning and predicting
3 planning investigations
4 conducting investigations
5 processing data and information
6 analysing data and information
7 problem-solving
8 communicating.

This section will break down each process for you – where to start a process, how you can apply it as you learn more, and how mastering the process will elevate your science learning.

The Learning Ladder and working scientifically

At the start of each focus area, each Learning Ladder lists the eight working scientifically processes that will be explored in that focus area and the five levels of progress for each of those processes.

Figure S2.2 shows the working scientifically Learning Ladder, 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 you in charge of your own learning progress.

Figure S2.2: Start at Step 1 and work your way up to mastery.

Learning Ladder

Steps in progression	Observing	Questioning and predicting	Planning investigations	Conducting investigations
5	I can select scientific equipment to improve the precision of my observations.	I can evaluate questions and hypotheses relating to scientific phenomena.	I can assess the type of data that can be collected in a range of investigations.	I can extract data from secondary sources and construct appropriate references to acknowledge their use.
4	I can use observations and measurements to answer questions.	I can formulate testable questions and predictions, considering variables and controls.	I can produce plans for investigations that are ethical, reliable and valid.	I can accurately collect and record data, information, evidence and findings from first-hand and second-hand investigations.
3	I can make inferences based on my observations.	I can propose hypotheses based on scientific knowledge.	I can develop appropriate scientific aims for a range of investigations.	I can conduct first-hand investigations and accurately record the collected data and identify errors.
2	I can record observations and measurements accurately.	I can construct questions to investigate scientific concepts or problems.	I can distinguish between controlled, dependent and independent variables.	I can use scientific equipment to conduct investigations and gather first-hand data and information.
1	I can use scientific tools to enhance observations.	I can select questions to investigate scientific concepts or problems.	I can describe ways to reduce risks for a range of investigations.	I can implement safe practices when using scientific equipment.

Working scientifically processes

Each section of this book contains a Learning Ladder question block. The questions relate to both the content and working scientifically processes. Question 1 corresponds to Step 1, Question 2 corresponds to Step 2, and so on.

The green headings mean these are working scientifically process questions. They will test you on a specific process, such as observing. There is a page reference to the relevant Science how-to section, where you can get more information on what is required at each step of the process.

The question numbers correspond to the steps on the Learning Ladder, so you can work to your level.

Learning Ladder

Energy

1. Identify the three main requirements when constructing a complete circuit. Explain why each is needed.
2. Describe what occurs when electrons flow around a closed circuit.

Observing

see page 398

1. Accurately copy the symbols from Table 1.6.
2. In Figure 1.14, which circuits are open and which are closed? How do you know?

In context

Investigate different types of cells and batteries and their uses. Identify strengths and weaknesses for each type of cell or battery. Construct a table to present your results. Hint: Identify each selection as cell or battery.

Success criteria

- I can identify the features and components of an electric circuit.

Next we will consider each working scientifically process and break down what is required at each step of the Learning Ladder to develop your skills and achieve process mastery.

Processing data and information	Analysing data and information	Problem-solving	Communicating	Steps in progression
I can evaluate investigations based on the quality of processed data.	I can evaluate conclusions based on the quality of data.	I can evaluate scientific claims based on evidence.	I can evaluate scientific findings based on secondary evidence and arguments.	5
I can use data to support or refute questions, hypotheses or solutions to problems.	I can assess data and information for accuracy, reliability and validity.	I can assess problem-solving strategies used to solve an identified problem.	I can present scientific findings using appropriate conventions for specific audiences.	4
I can process and interpret quantitative and qualitative data from a range of sources.	I can draw conclusions based on patterns in data and information.	I can use given criteria to find solutions to scientific problems.	I can construct a range of appropriate scientific presentations based on first-hand and second-hand data and information.	3
I can organise and represent data in appropriate ways, including in tables and graphs.	I can explain relationships between datasets and information.	I can explain scientific problems and phenomena using cause-and-effect relationships.	I can use digital technologies to organise and present data and information.	2
I can select and extract information from various texts and sources.	I can describe trends from collected data and information.	I can propose solutions to familiar scientific problems.	I can select appropriate ways to communicate information.	1

Observing

Observations are the basis of scientific investigation. By making observations, we are able to conduct investigations, record **data** and make inferences from what we can observe. Scientists first use their senses to make observations. Then, they use specialised equipment to refine and record these observations, so that they are more precise.

Step 1 I can use scientific tools to enhance observations

Even though our senses can provide us with information, often they are not precise or accurate. To make precise and accurate observations, we need to use scientific equipment to record our measurements during investigations.

To decide what equipment to use when observing, ask yourself:

- What am I trying to observe?
- What equipment would allow me to measure accurately and precisely?

Figure S2.3: Universal indicator is a scientific tool used for measuring pH levels. It turns red in acids and remains green in neutral solutions.

Table S2.1 shows some appropriate measurements and equipment.

Table S2.1: Determining the right scientific equipment

Question	Observation/s	Measurement	Scientific equipment
Does the length of a pendulum affect the time taken for it to swing back and forth?	The pendulum moves at different speeds	The time taken for one full period (one swing back and forth) to be completed	Time can be measured precisely and accurately with a stopwatch
What substances can be classed as acids?	The vinegar turned red when the indicator was added	Solutions can be measured as acids or bases using a pH scale	Universal indicator and charts allow us to interpret colours as quantitative measurements
Does changing fuel sources in combustion affect the rate at which water is heated?	Water bubbling; colour of flames of different fuel sources and residue on test tube	The difference in temperature of the water	A thermometer can measure the difference in temperature of the water that is heated

Step 2 I can record observations and measurements accurately

Once observations have been made using specific equipment, they need to be recorded accurately. To do this, the precise quantities need to be organised in an effective way so that they can be easily interpreted. One of the best ways to record observations is in a scientific table. To ensure your observations are accurate, include:

- headings showing what is being observed
- units of measurement that the observations are being recorded in.

For example, when recording data on temperature, the data should be neatly recorded in a column labelled 'Temperature (°C)'. More information on constructing scientific tables can be found in the 'Processing data and information' section on pages 412–20.

Figure S2.4: Stopwatches can be used to precisely and accurately record the time taken for a reaction to occur.

Step 3 I can make inferences based on my observations

Collecting and recording observations then allows us to interpret the information we are collecting. This interpretation is an inference – a conclusion that is drawn based on the observations we have made.

To make an inference, you need to decide what your observations are telling you. To do this, ask:

- What am I observing?
- What measurements have I recorded?
- What do these measurements tell me about my investigation?

For example: In an investigation, a student was looking at how the length of a pendulum affected its swing time. Table S2.2 shows the observations the student recorded.

Table S2.2: Investigation observations

String length (cm)	Time for one period (s)
30	1.1
40	1.3
50	1.4

Looking at the data, the student makes an inference that a longer string will cause the pendulum to swing more slowly.

Figure S2.5: Using scientific equipment to make observations can allow us to make inferences about the outcome of investigations.

Step 4 I can use observations and measurements to answer questions

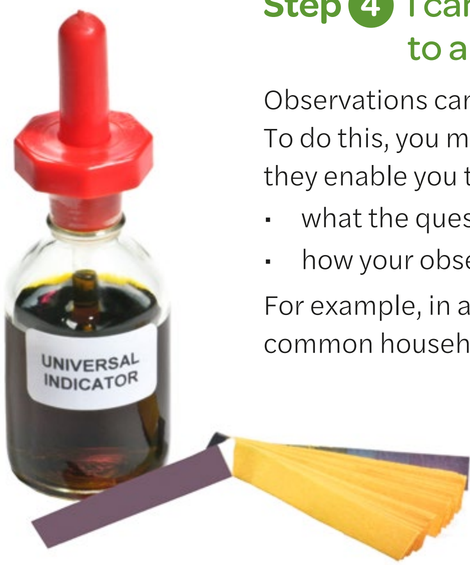


Figure S2.6: Universal indicator allows us to make observations that help to determine the pH of substances.

Observations can additionally be used to allow us to answer questions in investigations. To do this, you must look at the observations you have recorded and see which questions they enable you to respond to. When answering questions, you need to consider:

- what the question is asking
- how your observations can be used to respond to the question.

For example, in an investigation, a student was making observations about the pH of common household substances. They recorded their observations in Table S2.3.

Table S2.3: Observations of the pH of household substances

Substance	Colour	pH
Lemon juice	Red	2
Water	Green	7
Baking soda	Blue	8

They are then asked the question: Which substance could be used to neutralise vinegar, which has a pH of 2?

Using their observations, the student writes a response to the question: 'Baking soda is a base and could be used to neutralise vinegar.'

Step 5 I can select scientific equipment to improve the precision of my observations

Scientific equipment can help us to make precise measurements. It is important, therefore, to know how to select the *best* piece of equipment that will improve our observations. Selecting the best piece of equipment will improve the precision of our measurements, making our investigation more accurate.

To select the best piece of scientific equipment, ask yourself:

1. What equipment would allow me to measure accurately and precisely?
2. Which version of this equipment will give me the smallest margin of error on my measurements?

Table S2.4: Selecting the most precise scientific equipment for a measurement is important, as it improves precision and helps to reduce errors in investigations.

Measurement	Scientific equipment	Most precise equipment
Temperature	Thermometer	A digital thermometer: This will help me to measure to within 0.1 °C, rather than within 1.0 °C using an alcohol thermometer.
pH	Indicator, or pH probe	The pH probe: This will help to measure pH to two decimal places, rather than using whole numbers.

Figure S2.7: A digital thermometer provides higher precision of measurement than an alcohol thermometer.

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 select questions to investigate scientific concepts or problems

Scientific questions contain one factor that we can change during an investigation and one factor that 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. Table S2.5 shows how.

Table S2.5: What to look for when setting up an investigation

Question	Thing changed	Thing you can measure	Can it be investigated?
How does the mode of agitation (stirring) affect the rate of a chemical reaction?	The mode of agitation: swirl by hand, magnetic stirrer.	The rate of reaction – e.g. the time it takes for the reaction to go to completion.	Yes
What is the rate of reaction between vinegar and baking soda?	Nothing – there are many things that could be changed, but none are included in the question.	The rate of reaction. But without a cause, the measurement has no context.	No

The first question in Table S2.5 *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 change; the measurement would be irrelevant.

Step 2 I can construct questions to investigate scientific concepts or 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?

Figure S2.8: The independent variable (stirring) has an effect on the dependent variable (reaction rate).

Figure S2.9: The angle of the Sun's rays on a solar panel affects the amount of electricity it can generate – but how?

For example, we may have the following scientific problem: The Sun shining on solar panels generates different amounts of energy, depending on the angle of the Sun's rays, which changes throughout the day. So, our question is:

How does the angle of incidence of sunlight impact the amount of electricity solar panels can generate?

The independent variable is the angle of incidence of the Sun's rays on the solar panel. The dependent variable is the amount of electricity generated. The additional step is to identify the relationship. In our example, we are testing the relationship between angle of incidence and amount of electricity generated.

Step 3 I can propose hypotheses based on scientific knowledge

The next level up is to use scientific knowledge to help you make predictions. When written correctly, often using an 'If ______, then ______' statement, your prediction is considered an experimental **hypothesis** because it will be supported or rejected by the results of the investigation. The factors identified in Step 2 can be used to help you fill in the blanks of your 'If ______, then ______' statement:

IF [the factor you change],
THEN [the factor you measure and predicted outcome].

To base your prediction on scientific knowledge, you must match the content that relates to the investigation factors. When you make links to scientific theory to select a predicted effect, your 'If ______, then ______' statement will be followed by a 'because ______' statement to show why you think that will be the outcome.

IF the angle of incidence of light hitting the solar panel is decreased, *THEN* it will generate more electricity, *BECAUSE* less light is reflected off the surface, allowing more to be absorbed and converted from solar energy to electrical energy by the photovoltaic cells.

Step 4 I can formulate testable questions and predictions, considering variables and controls

To create testable questions and predictions, you need to be able to identify the independent and dependent variables and some *controlled variables,* which are things that could be kept the same.

The following method will help you to formulate a scientific question:

a Read the question.

b Identify the independent variable.

c Identify the dependent variable.

d Identify some controlled variables.

Now that you can write and support a prediction generally, you can update your prediction with the specific variables of the investigation. This means we can also look at the relationship between the variables. 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.

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:

IF [the independent variable and the specific change],
THEN [the dependent variable and the predicted effect].

Step 5 I can evaluate questions and hypotheses relating to scientific phenomena

In the previous four steps, you refined your ability to structure scientific questions and predictions, as well as to support your predictions. In Step 5, the focus is on **evaluating** questions and predictions. Is the question or prediction reasonable and **plausible**? This is a higher-order thinking skill that requires you to think critically about questions and predictions.

- Do they include everything they should?
- Do they exclude things that are not appropriate?
- Can they be tested and answered fairly?

These are the questions you need to ask in order to evaluate scientific questions and hypotheses and to show a deeper understanding of the skills in Steps 1 to 4.

Use the following checklists to evaluate questions and hypotheses:

QUESTIONING CHECKLIST

- [ ] It is a question; therefore, it ends with a question mark.
- [ ] It is not a definitive question; i.e. it is not a 'yes' or 'no' question and does not require a particular answer, such as a 'this' or 'that' response.
- [ ] It includes a factor that can be changed (independent variable) and a factor that can be measured (dependent variable).
- [ ] It can be investigated.

HYPOTHESIS CHECKLIST

- ☐ States the predicted effect in a statement that can be structured using the '*If* [independent variable and specific change], *then* [dependent variable and predicted effect], *because* [scientific theory]' template.
- ☐ Includes the independent variables and associated change.
- ☐ Includes the dependent variables and the predicted effect in relation to the change.
- ☐ Includes an explanation of scientific theory that justifies the prediction.

If anything from the checklist is missing, you should be able to use your knowledge to modify or adjust the question/prediction so that it meets the required standards.

- Make a judgement on whether or not this is a good scientific question.
- Suggest any improvements for the question or prediction, then rewrite it.

Table S2.6 shows how you can evaluate a scientific question and a scientific prediction.

Table S2.6: What to look for when setting up an investigation

Question: How does the *mode of agitation* (stirring) affect the *rate of a chemical reaction*?	
Independent variable	The mode of agitation: swirl by hand, magnetic stirrer
Dependent variable	Rate of reaction
Controlled variables	None
Judgement	This is a good scientific question that changes only one factor; however, it should specify how the rate of reaction will be measured, e.g. volume of gas generated over time. To improve it further, it should also include the controlled variables.
Improvement	This question could be improved by controlling the variables, stating how the dependent variable will be measured. The details of the chemical reaction under investigation should be included. For example, all factors that affect rate of reactions, besides agitation – temperature, concentration, and surface area of reactants – must all be controlled and be kept the same.
Prediction: If the angle of incidence of light hitting the solar panel is decreased, then it will generate more electricity because less light is reflected off the surface. This allows more light to be absorbed and converted from solar energy to electrical energy by the photovoltaic cells.	
Independent variable	The angle of incidence of sunlight hitting the solar panel surface
Dependent variable and predicted effect	The amount of electricity generated is expected to increase as the angle decreases
Controlled variables	One – the source of light: the Sun
Scientific knowledge: Prediction is justified by reflection/absorption theory	
Judgement	This is an excellent scientific hypothesis that includes one changed and one measured variable, as well as the predicted effect. It also includes how the investigation is controlled, and is justified by scientific knowledge. No improvements are required.

▲ **Figure S2.10:** It is important to use safety equipment such as gloves and laboratory coats when working with biological specimens, to prevent them contacting your skin.

Planning investigations

Planning will help you to come up with well-constructed investigations to answer scientific questions. A well-planned investigation should use appropriate scientific equipment, follow specific and ordered steps, and contain multiple trials, so that any data collected can be deemed accurate, valid and reliable.

Step 1 I can describe ways to reduce 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, in an investigation, the equipment is:

- Bunsen burner
- water
- beaker
- gauze mat
- box of matches
- measuring cylinder
- tripod
- thermometer.

How could this equipment cause harm, and what can you do to reduce the risk?

- The Bunsen burner, box of matches and boiling water could cause burns if they touch skin. I can reduce the risk of harm by keeping my hands away from the flames of the Bunsen burner and match, and by keeping a safe distance from the boiling water and by wearing a laboratory coat.
- The boiling water could hurt someone's eye if it splashes. I can reduce this risk by making sure to wear safety glasses.
- Someone could slip if water is spilled. I can reduce this risk by only adding water to the beaker after it is at the bench.
- The measuring cylinder, beaker and thermometer 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 don't fall on the floor.
- The tripod and gauze mat could cause burns after they have been heated. I can reduce this risk by leaving them to cool down before packing away my equipment.

Figure S2.11: A heat absorption investigation – what will you change and what will you measure?

Step 2 I can distinguish between controlled, dependent and independent variables

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 other variables that you will have to control (i.e. keep the same). 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 determine if the colour of a material affects its heat absorption properties.

- *What am I trying to investigate?*
  How does the colour of a material affect the amount of heat it absorbs?
- *What one factor should I change?*
  I can see from the question that the colour of the material will need to be changed – this will be my *independent variable.*
- *What one factor should I measure?*
  The question asks if the heat absorption will be different, so I should measure the temperature of the material – this will be my *dependent variable.*
- *What factors will I need to control?*
  To test heat absorption, I will leave the different-coloured materials in the sun. So, each time, I should use the same controlled variables:
  - type of material
  - amount of material
  - environmental conditions
  - time left in the sun.

Step 3 I can develop appropriate scientific aims for a range of investigations

A scientific aim links together the independent and dependent variables of a first-hand investigation. This statement is used to show the purpose of a first-hand investigation. We want to see if there is a relationship between these two variables. In our scientific aim structure, it looks like this:

To determine the effect of the independent variable on the dependent variable.

For example, we may have the following scientific problem: The amount of heat a material absorbs changes, depending on its colour. So, our aim is to determine how the colour of a material affects the amount of heat it absorbs in one hour. The independent variable is the colour of the material. The dependent variable is the amount the temperature increases. In our example, we are testing the relationship between colour and heat absorption.

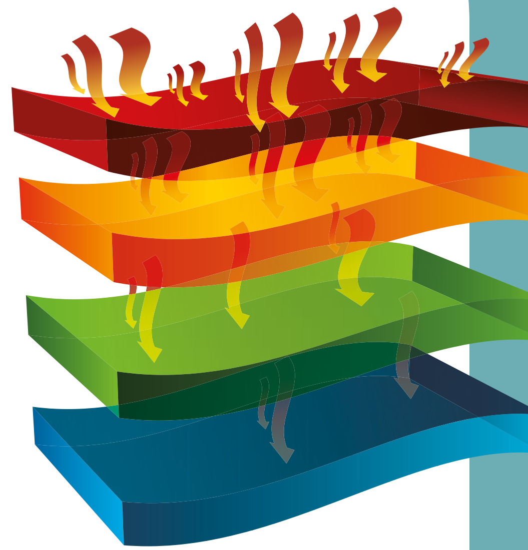


Figure S2.12: Our aim shows us the purpose of our investigation. We can investigate the link between the colour of a material and how much heat it can absorb.

Step 4 I can produce plans for investigations that are ethical, reliable and valid

Before conducting an investigation, you should 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 colour of a material affect the amount of heat energy it can absorb?

Our method or procedure would follow the process below:

1. Collect all the necessary equipment.
2. Find a sunny surface that is not impacted by other environmental factors such as wind.
3. Cut out five 10 × 10 cm squares of material in five different colours – black, white, red, yellow and blue.
4. Use a digital thermometer to record the initial temperature of each material.
5. Place the materials on the sunny surface and secure in place with tape.
6. Use the digital thermometer to measure the temperature of each piece of material every 15 minutes for one hour.
7. Record the temperatures in a results table.
8. Repeat steps 3–7 two more times, using the same environment, material size, type and colours.

Step 5 I can assess the type of data that can be collected in a range of investigations

When planning an investigation, it is important to consider the type of data you are going to be collecting. Some investigations produce quantitative data; for others, qualitative data is more appropriate.

To assess the data required, ask yourself:

1. Can I record numerical values from this investigation?
2. Which type of data would be beneficial when drawing conclusions from this investigation?
3. What limitations could occur from the data collected?

Figure S2.13: Weighing up the benefits and limitations of different data types can help us to make a judgement on which will be the most useful when conducting a first-hand investigation.

For example, in the heat absorption investigation planned above:

1 Can I record numerical values from this investigation?
  Yes – I can record the temperature in degrees Celsius, which is quantitative data.
2 Which type of data would be beneficial when drawing conclusions from this investigation?
  Having quantitative data would be beneficial, because it will show a precise temperature difference between the materials, so I can measure small differences between the colours.
3 What limitations could occur from the data collected?
  If I use qualitative data and record my observations, I may not be able to feel a difference in the material temperatures, which would limit the accuracy and validity of the investigation.

So, in this investigation, a judgement can be made that quantitative data – of the temperature change in degrees Celsius – is the most useful data for this investigation.

Conducting investigations

When conducting investigations, you follow a series of steps while using the appropriate equipment and maintaining safety standards. This will result in reliable results to test your hypothesis, which you can compare to existing data testing the same hypothesis.

Step 1 I can implement safe practices when using scientific equipment

Risks you describe when planning an investigation can be structured in a table such as Table S2.7. 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 keeping everyone safe.

Table S2.7: Reducing risks when working with acids and bases

Hazard	Risk	Strategy
Universal indicator	High likelihood of eye damage if splashes into the eye	• Use a pipette to transfer indicator from container to test tube. • Wear safety glasses to create a barrier between indicator and eyes.
Hydrochloric acid	High likelihood of burns if it splashes onto skin	• Use a pipette to transfer acid from the container to the test tube. • Wear gloves and long sleeves to prevent acid from coming into contact with skin.
Glass test tube	Very high likelihood of cuts if glassware breaks	• Never run while carrying glassware. • Place test tube in a test tube rack away from the edge of the lab bench to prevent it from being knocked onto the floor.

Step 2 I can use scientific equipment to conduct investigations and gather first-hand data and information

To conduct an investigation, you should:

- read through all the steps before starting
- collect all the pieces of equipment listed
- complete all parts of a step before moving to the next one.

As an example, imagine we want to investigate the following question:

How can we measure the pH of common household substances?

Figure S2.14: A first-hand investigation can be conducted to test the pH of common household substances.

The investigation lists the following procedure:

1 Place six test tubes into a test tube rack.
2 Measure 5 mL of hydrochloric acid and each household substance into test tubes using measuring cylinder.
3 Use a pipette to transfer six drops of universal indicator into each test tube.
4 Observe and record colour changes in a results table.
5 Use a universal indicator chart to record numerical pH value for each substance.
6 Classify substances as acidic, basic or neutral.

We should read through every step. Then we need to collect all the equipment:

- test tubes
- pipette
- household substances
- universal indicator chart
- test tube rack
- hydrochloric acid
- universal indicator
- 20 mL measuring cylinder.

Finally, we need to complete all parts of each step before moving onto the next one. So, for the first step of our investigation, we would place six test tubes into a test tube rack.

Step 3 I can conduct first-hand investigations and accurately record the collected data and identify errors

As well as being safe, your investigations must also be **ethical** – that is, you must conduct your investigation with integrity, and ensure that data is collected accurately and recorded honestly. To check that an investigation is safe and ethical, you must ensure:

- you or your teacher have conducted an appropriate risk assessment for the investigation
- the equipment used is appropriate for what you are investigating, to help minimise errors
- the investigation is conducted honestly; no one tries to skew the test or measurement to obtain a certain result
- the data is recorded exactly as it is measured.

Figure S2.15: Using safety gear minimises the likelihood that someone will be injured during an investigation.

You can use a checklist to help you confirm that your investigation is safe and ethical.

SAFE AND ETHICAL INVESTIGATION CHECKLIST

- ☐ I made a risk assessment that identifies at least three hazards and how to prevent them from happening.
- ☐ I chose equipment that allows me to conduct the investigation and measure results accurately.
- ☐ I recorded the data I collected exactly as measured in a results table.

Step 4 I can accurately collect and record data, information, evidence and findings from first-hand and second-hand investigations

As well as being safe, your investigations must also ensure that data is collected accurately and recorded honestly. To check that data is recorded accurately:

- construct a results table to record data about the independent and dependent variables of the investigation
- ensure the equipment used is appropriate for what you are testing
- record the data exactly as it is measured.

You can use a checklist to help you confirm your data is recorded accurately.

ACCURATE DATA-RECORDING CHECKLIST

- ☐ I constructed a results table that allows me to record data about the independent and dependent variables.
- ☐ I chose equipment that allows me to conduct the investigation and measure quantities precisely and accurately.
- ☐ I recorded the data I collected exactly as measured in a results table.

When you repeat a test or investigation and the data you collect is the same or similar every time, your data is reliable. To collect reliable data, you should:

- conduct the investigation and record the data
- repeat the investigation at least twice more and check that the data is the same each time, within a reasonable margin
- use your repeated trials to generate average data values.

Scientific investigations can contain either random errors or systematic errors (or both). A *random error* occurs by chance, and can be from changes in the way we make and record measurements, or from changes in the environment. A *systematic error* is when a measurement is consistently off, which usually occurs from using imprecise or incorrectly calibrated equipment.

To identify errors, compare data to other tests to look at the level of similarity. If there are differences, check the procedure and equipment to rule out systematic errors. Where none can be found, there may be a random error. To identify any errors, re-check the procedure to find any areas that may have caused differences in your results.

Step 5 I can extract data from secondary sources and construct appropriate references to acknowledge their use.

It is important not only to be able to carry out first-hand investigations, but also to extract data and information from second-hand sources on investigations that have been carried out by other scientists. Extracting data requires reading through scientific articles and investigation reports and focusing on the results that were obtained. Any time results are used from a secondary source, they must be appropriately acknowledged using a reference.

To extract data from a secondary source:

1 Read through the information in the article and/or investigation to make sure it relates to your investigation or question.
2 Write a TEEL paragraph summarising the data from the investigation. (See the 'Scientific writing' section on page 444 to help with this structure.)
3 Check the discussion and conclusion to make sure that any errors in the investigation were accounted for.
4 Construct and record a reference acknowledging the source. (See the 'Scientific writing' section on page 443 to help with constructing references.)

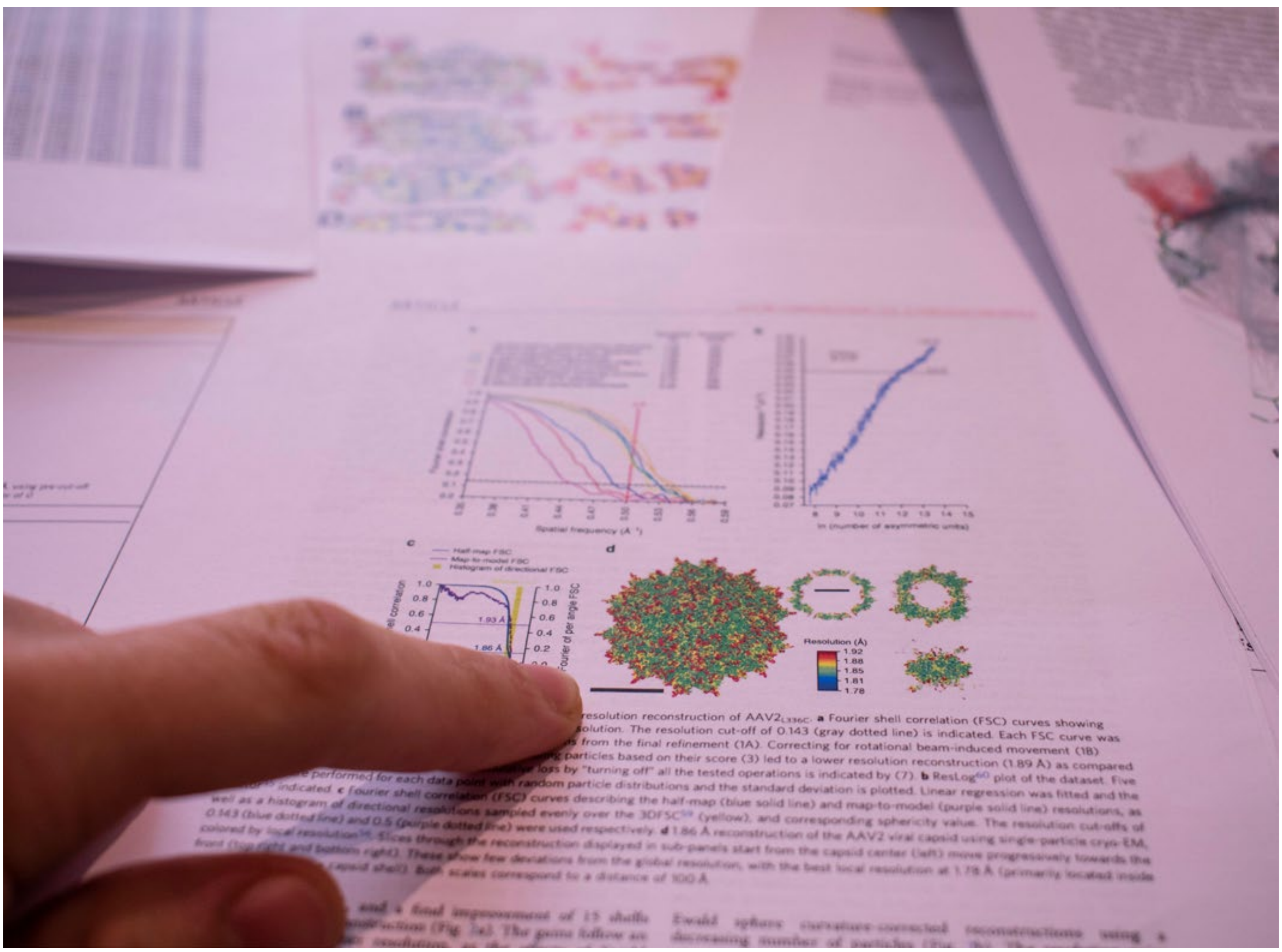


Figure S2.16: Data from secondary sources can be extracted to help corroborate our own investigation results or when we are unable to conduct our own first-hand investigation.

Processing data and information

Information generated during a scientific investigation should be recorded in an organised way, so that you can process it. Processing your data means presenting information in a way that clearly displays what you have found. This will help you to identify, understand and evaluate the data you have collected.

Step 1 I can select and extract information from various texts and sources

The first step in processing data is simply recognising and selecting 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 S2.8 is organised in a way that clearly displays information. From the title, we can recognise that the data will show us how the rate of the reaction is affected by agitation. The headings indicate that measurements were taken in millilitres every 10 seconds for 60 seconds, and the values in the table show the volume of gas evolved from each reaction for each of the three modes of agitation.

Table S2.8: Effect of mode of agitation (stirring) on rate of reaction

Mode of agitation (independent variable)	Volume (mL) of gas collected every 10 seconds over 1 minute (dependent variable)					
	10 s	20 s	30 s	40 s	50 s	60 s
Swirl every 10 seconds	0	5	12	18	21	23
Swirl continuously	8	17	28	36	41	47
Continuous magnetic stir	10	20	35	45	50	53

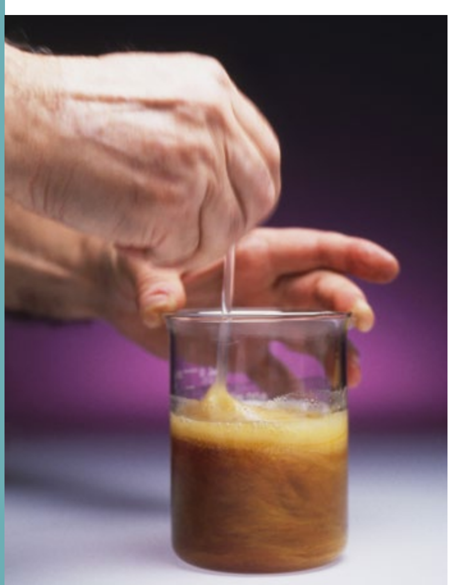


Figure S2.17: Because the chemical reaction under investigation happens quickly, it makes sense to measure the gas evolved in millilitres (mL) every 10 seconds as recorded in Table S2.8.

Step 2 I can organise and represent data in appropriate ways, including in tables and graphs

Being able to organise and represent the data you collect in an investigation is the next step in processing data and information. Tables can be used to organise your data, while graphs are used to represent the data that has been collected. There are also other ways to display the findings of an investigation, as explained in this step.

Constructing tables to organise data

Follow these instructions to prepare your own table to organise data for a particular investigation:

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 S2.8 we list the modes of agitation down the left column (independent variable). Then we have a main heading for the measurement that will be taken (the dependent variable), which is divided into six columns for each of the 10-second intervals when measurements are recorded.

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). (A **data point** is a single identified element in a dataset.) In Table S2.8, we have three datasets: one for each mode of agitation: (1) swirl every 10 seconds; (2) swirl continuously; and (3) continuous magnetic swirl. 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 10-second time intervals across the first minute of reaction time. 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 make sure there is enough room to write the information clearly.

d Write headings to represent the variables. The left column includes the variations of the independent variable: the three modes of agitation. Ensure your headings give the reader a clear picture of the data collected, including the units of measurement used.

The next 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. For example:
*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.

You are now ready to conduct the investigation and record the data, as shown in Table S2.9.

Table S2.9: Effect of wheel type on distance travelled over three trials

Wheel type (independent variable)	Distance travelled (cm) (dependent variable)			
	Trial 1	**Trial 2**	**Trial 3**	**Average**
Bottle cap	*11*	*9*	*13*	*(11 + 9 + 13) ÷ 3 = 11*
Compact disc	*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 on calculating averages, see pages 451–52.

Constructing graphs to represent data

To represent information from a table, take your data and show it in a graph. Graphs are useful for displaying data, as they can be easier to understand and interpret than descriptive text. The three graphs we will use most often in science are the column graph, the line graph and the scatter plot, shown in Figure S2.18.

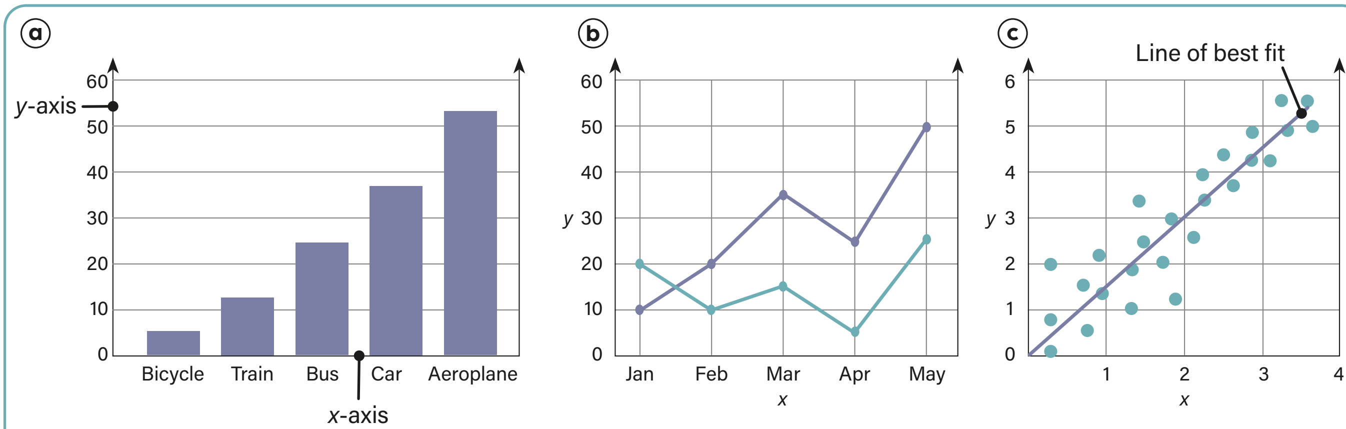


Figure S2.18: Three types of graph used in science: (a) a column graph; (b) a line graph; and (c) a scatter plot, with a 'line of best fit' running through the middle

Figure S2.19 is a column graph of the results of the model car investigation. The annotation describes how to construct the graph.

ⓐ Determine the range of the axes based on the data collected and recorded in Table S2.9.

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.

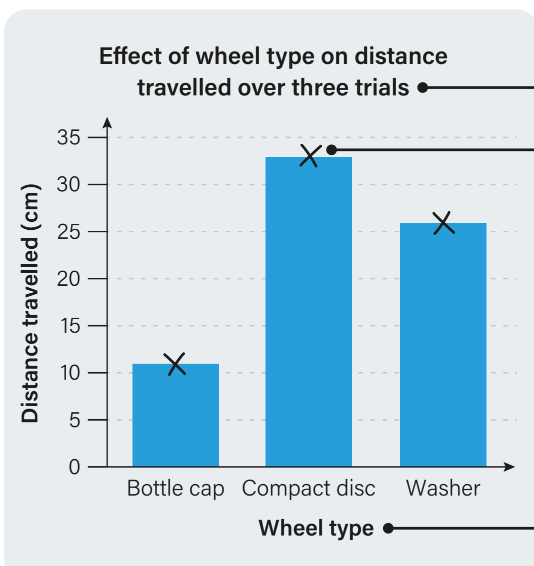


Figure S2.19: A column graph of the results of a model car investigation using the data from Table S2.9.

ⓒ 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. Include the unit of measurement, if needed, on each axis label.

ⓓ 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.)

ⓑ Use a ruler to draw the axes and mark the intervals between values. Since the *y*-axis must cover values 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 clutter the graph.

Categorical factors like the wheel type are best represented in a column graph, as shown in Figure S2.19. 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**.

Representing data in a range of formats

When choosing how to display your findings, you need to select the right visual for your information, just like picking the right tool for a job. Figures S2.20 to S2.24 show some ways you can visually communicate information.

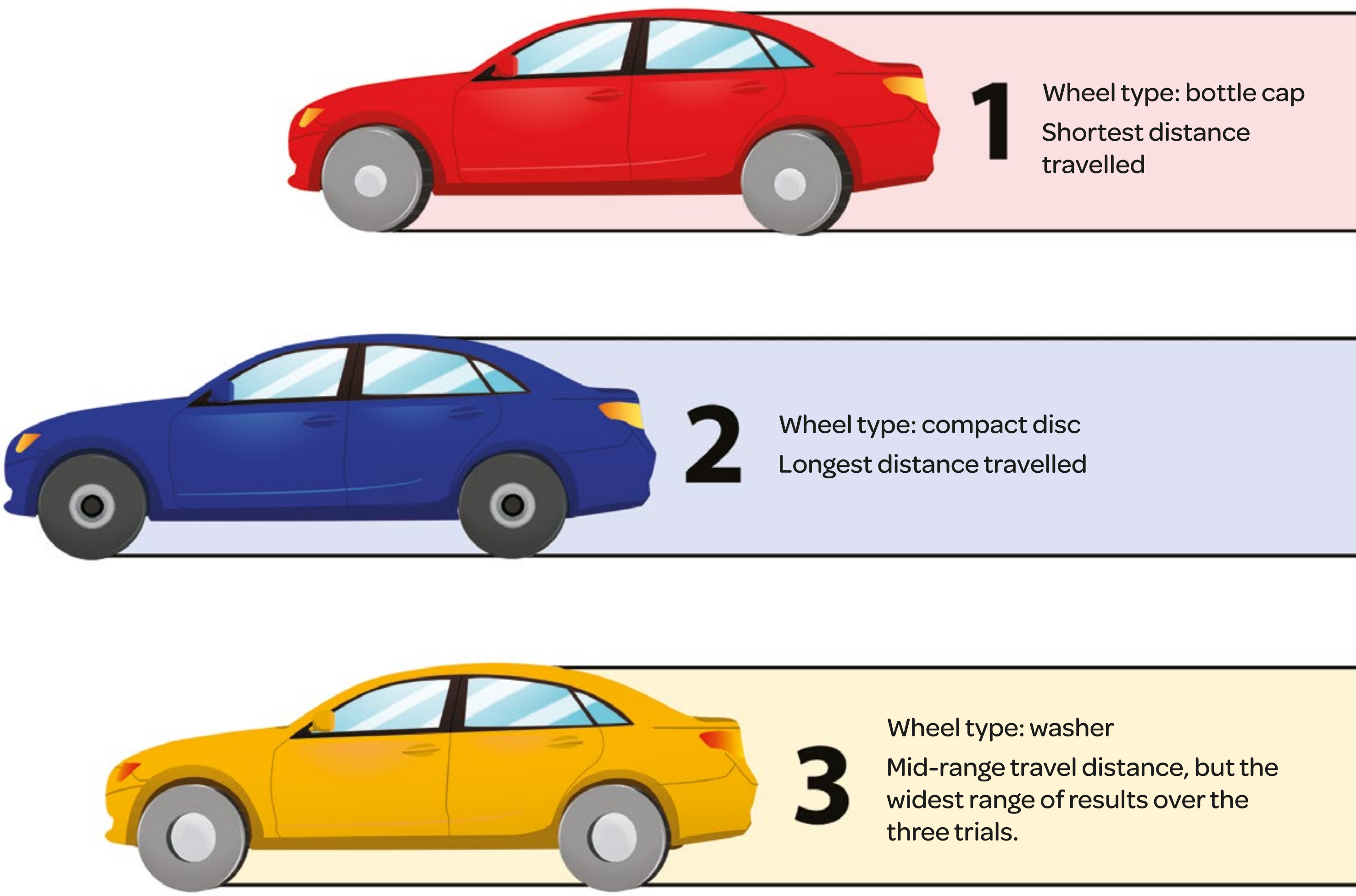
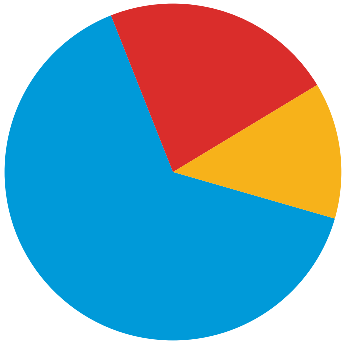


Figure S2.20: An infographic showing the model car investigation results

Figure S2.21: A pie chart is best for looking at the parts that make up a whole.



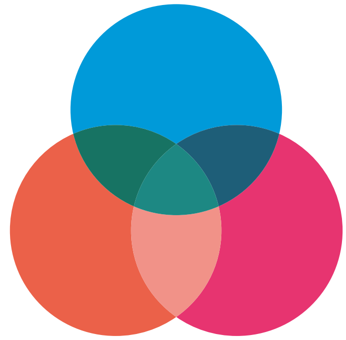


Figure S2.22: A Venn diagram is used to compare similarities and differences.

Figure S2.23: A word cloud is a creative way to show different proportions.

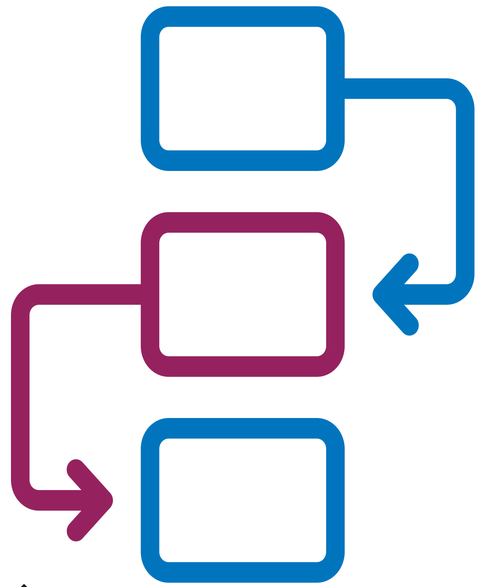


Figure S2.24: A flow diagram can be used to show how one thing moves or transforms to another.

Step 3 I can process and interpret quantitative and qualitative data from a range of sources

The most challenging aspect of processing data is being able to understand what it means, no matter how it is presented. In Step 2, the focus was on presenting data using tables, graphs and other visual formats. Now that you have worked your way through the different modes of representation, you should be able to interpret what is being presented, no matter the type of data or the format in which it is presented.

Not only are you able to process raw data into tables and graphs, but you can also understand what the data is communicating. To display your skill at this level, you should be able to explain how the raw data should be or has been adapted to communicate a variety of possible investigation results in a clear and focused way.

Consider Table S2.8 on page 412. Try to summarise the important aspects of the data, without being prompted by questions like those from Step 1. The summary could be in the form of a written paragraph or simply a discussion with your peers about the story that this data shares with the audience.

Step 4 I can use data to support or refute questions, hypotheses or solutions to problems

The aim of most investigations is to answer the research question and determine if the hypothesis is supported by the data. This step requires higher-level thinking skills to consider the processed data in relation to the scientific question, hypothesis and possible solutions to problems.

Consider the investigation from steps 2 and 3:

How does the type of wheel – bottle cap, compact disc (CD) or washer – affect the distance travelled by a model car?

From this research question, we can assume that the problem is to improve the efficiency of wheels. Now, suppose the hypothesis predicts that the bottle cap will be the most efficient 'wheel'. We can see clearly in the represented data that the bottle cap is the *least* efficient, which refutes (disagrees with) the hypothesis. The data could be used to refute the question, as it specifically references three wheel types. While the CD wheel is supported as the most efficient in this investigation, these three objects are a limited representation of circular items that could be used to construct wheels. Therefore, more questions could be asked to investigate whether or not CDs remain supported as the most efficient wheel type.

If someone were to propose a solution that uses bottle caps for model cars, this could be easily refuted by the data collected in the experiment, as displayed in Figure S2.19. Bottle caps were the least efficient 'wheel'. Conversely, if CDs were proposed as the solution to the problem, this would be supported by the data, and CDs could therefore be the focus of the next investigation.

Step 5 I can evaluate investigations based on the quality of processed data

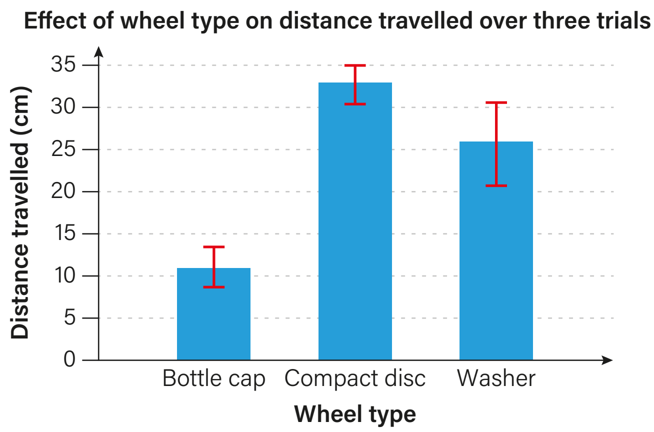
Assessing the quality of the processed data

The quality of the processed data has a direct link to the quality of the investigation method. Using descriptive statistics to process and represent data can help to inform how we establish the quality of the data.

Including statistics in a graph is helpful, because it lets us understand the data better. Statistics gives us numbers that show the average, trends and differences. If these things can be displayed visually, the graph will be more informative and will help people to determine the general quality of the processed data.

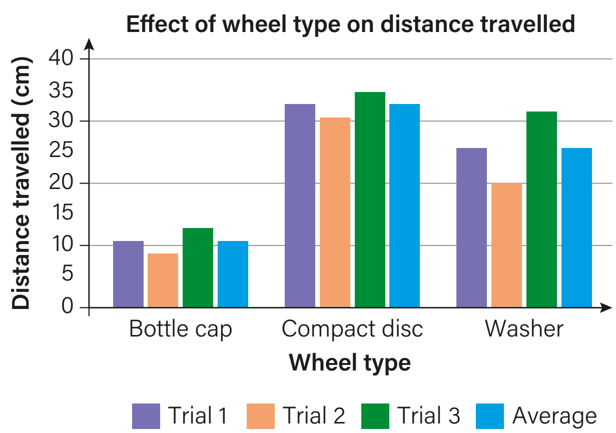
Consider the data from Table S2.9. The graph of this data in Figure S2.19 does not include any information about the individual trials, which could be very important when analysing it. To reach Step 5 of the Learning Ladder, you must consider the spread of data collected across all trials, and thereby indicate the quality of the data collected. This can be done by showing error bars on your datasets (see Figure S2.25), or by displaying a bar for each trial, as well as the average (see Figure S2.26).

The following are examples of what it might look like to incorporate descriptive statistics into a graph.



The error bars on each data bar show the minimum and maximum spread of data. The larger the error bar, the less precise the trial data.

Figure S2.25: Effect of wheel type on average distance travelled over three trials



Four bars are shown for each wheel type, including all three trials as well as the average. It is clear that the 'washer' dataset is not as precise as the bottle cap and compact disc trials.

Figure S2.26: Effect of wheel type on distance travelled

The error bars show a range of values that includes the true value somewhere within that range. This means we cannot be sure of the exact true value. Therefore, if the error bars overlap from one dataset to the next, the true value for each dataset could be the same. This is not ideal when you are trying to answer a question scientifically.

If the error bars across datasets do not overlap, the quality of the data is good. The smaller the individual errors bars, the higher the quality of the data.

If error bars overlap, the quality is not good. The more overlap that exists across the error bars, the lower the quality of the data.

Consider Figure S2.27. Due to the overlap in error bars across four of the five datasets, this data would be considered very low in quality. The only valid finding that can be drawn from this data is that 'B' is higher than the others. Since error bars give a range of where the true value might be, there is no way to know with certainty how A, C, D and E compare to each other.

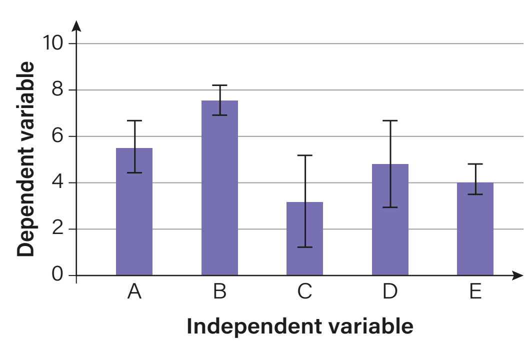


Figure S2.27

Discussing how modifications can improve the quality of the investigation

Once the quality of the data is determined, the investigation method itself can be evaluated. You must be able to discuss how the method can be modified to improve the quality of data. This is not as simple as just suggesting ways to change the method to make it better. You have to understand *how* and *why* it makes it better. This skill requires a deeper understanding of the impact of the modification and how it increases the quality of data to better address the investigation question.

For each error identified in a method, you should be able to discuss modifications that minimise their impact. Use this checklist to help you.

CHECKLIST FOR DISCUSSING HOW MODIFICATION CAN IMPROVE THE INVESTIGATION

- ☐ Consider the errors identified in the method.
- ☐ Suggest a modification for each source of error that will minimise its impact.
- ☐ Provide specific details for how the modification reduces error, including scientific theory where appropriate.
- ☐ Make links between modifications and the overall quality of the investigation.

First, we will identify some errors from the wheel-type investigation. Then, we can suggest modifications and consider how they minimise the errors, with reference to the quality of the investigation. (The text colours in the 'Discussion' column in Table S2.10 coincide with the checklist above.)

Table S2.10: Sources of errors in the investigation

Source of error	Explanation of how the error affects the quality of data	Discussion of how modifications can improve the investigation
Inconsistent ramp angle for each car (systematic error)	The distance travelled for the compact disc (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 reduces the validity of the results, as we cannot be sure if the CD would have gone further than the other cars had the test been done on a standard ramp.	*There must be three identical boxes so all three ramps are propped to the same height. The ramp angle determines how much gravitational force the car will experience down the ramp, impacting the distance it will go. This must be consistent across all trials to remove the ramp angle as a source of error. The ramp angle is a variable that should be controlled. Requiring identical boxes to prop the ramp will ensure a fair test.*
The way the distance was measured was inconsistent between cars (random error)	As a result of inconsistent measuring, there is no way to know how much or in what direction the values vary 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.	Measure the total distance that the car travels, even if it does not go in a straight line. Otherwise, the measured value will be shorter than the actual distance travelled, like cutting corners. Since the car going straight or curved was unpredictable, measuring the exact patch of the car reduces the random measurement errors, increasing the precision of the values collected. This improves the quality of data, making the key finding more valid, which improves the overall investigation.

Students often recommend repeated measurements, or MORE TRIALS, to improve the method. This works for random errors, but NOT for systematic errors, as summarised in Table S2.11.

Table S2.11: The impact of repeating measurements on random vs. systematic errors

Type	Impact of repeating measurements	Why
Random error	Increasing the number of trials DOES reduce the impact of random errors on the average results.	The more repeat measurements there are, the closer the average will be to the true value, which means the investigation questions can be answered more accurately.
Systematic error	Increasing the number of trials DOES NOT reduce the impact of systematic errors on the average results.	The error is consistent and predictable for every trial, so more trials will not 'average out' the error. The values are already precise, just not accurate or reflective of the true value. Therefore, the only way to minimise the impact of a systematic error is to address the problem in the method.

Analysing data and information

Analysing data is like being a detective for numbers! We need to make sense of information to reveal the key findings of our investigations. Being able to analyse data helps people to make informed decisions, solve problems and predict future trends.

Step 1 I can describe trends from collected data and information

Figure S2.28: The green line is trending up while the red line is trending down.

In order to describe a trend, we must first identify it, which you learnt to do in Stage 4 Science. To recap, 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 S2.28. A **pattern** is when the data repeats in predictable ways. Sometimes your data has no clear trend, so your data representation will display random values, or there may be a sideways trend (a horizontal line). A sideways trend means the value may trend up or down in small amounts but there is no *clear* upward or downward trend.

Figure S2.29 is a graph of snake sightings. It shows a trend downwards from January to June and a trend upwards from July to December, but no year-wide trend.

To recognise patterns, look for recurring values or repeating shapes. For example, in Figure S2.29 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.

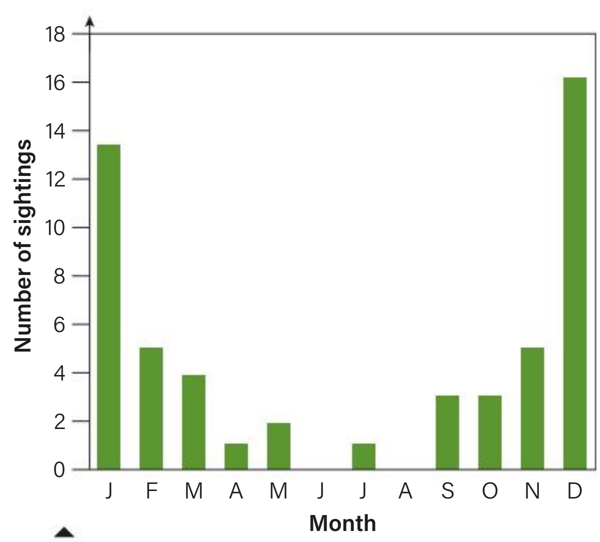


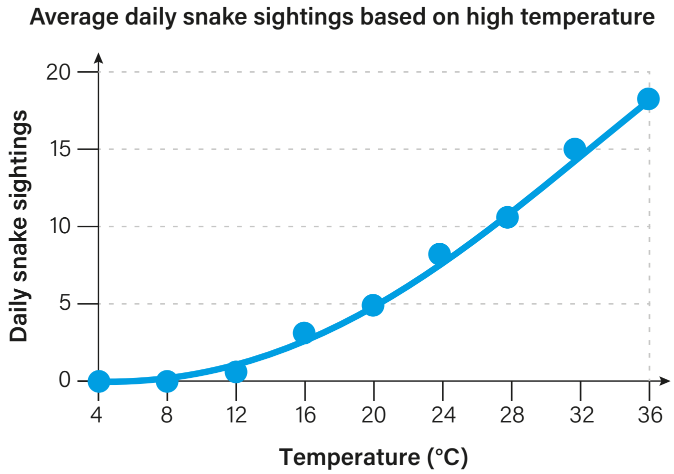
Figure S2.29: Snake sightings, average per month

We already identified the trends in the graph in Figure S2.29: 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.

To demonstrate the skill required in this step, you must 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:

Figure S2.30: The number of snake sightings increases with average temperature across the year.

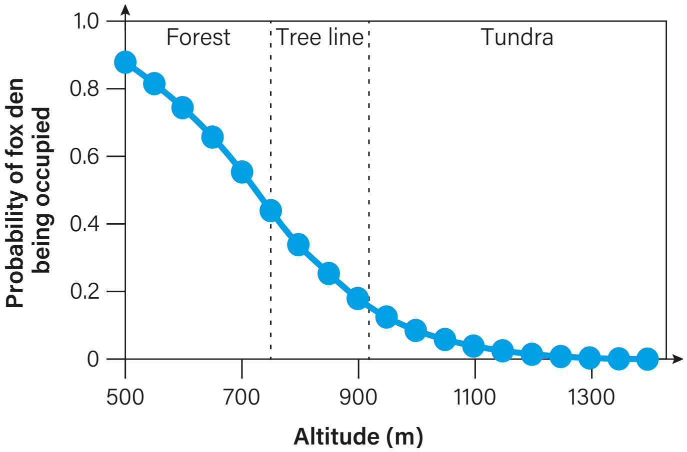
- *Positive correlation*: the relationship between variables is direct. This means that if the value of one variable increases, the value of the other variable also increases. The variables move in the same direction in a positive correlation.



This graph shows a positive correlation. As the temperature increases, so does the number of snake sightings. The relationship between temperature and the number of snake sightings is direct.

Figure S2.31: A line graph of snake sightings at different temperatures, showing a positive correlation.

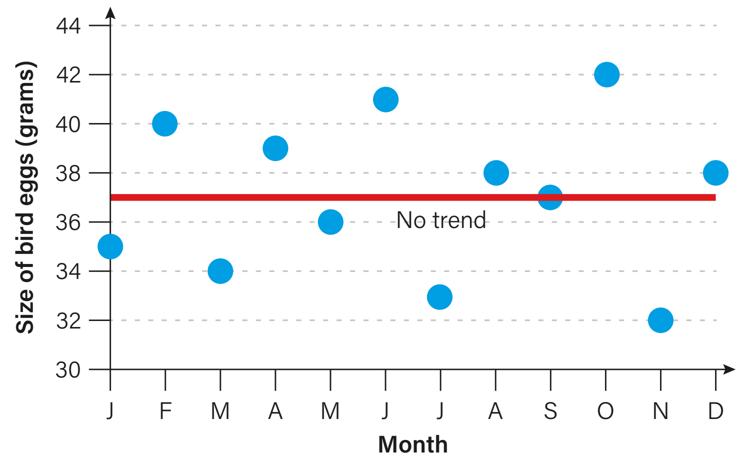
- *Negative correlation*: the relationship between variables is indirect. This means that if the value of one variable changes in one direction, the value of the other variable does the opposite. The variables move in different directions in a negative correlation.



This graph shows a negative correlation. The likelihood of a fox den being occupied decreases as the altitude of the habitat increases. If one goes up, the other goes down.

Figure S2.32: A line graph of fox den occupation rates, showing a negative correlation.

- *No correlation*: there is no apparent relationship between the variables.



There does not appear to be a correlation in the data of this graph. This indicates there is no relationship between the size of bird eggs and the month of the year. We cannot predict the size of bird eggs in a particular month because the data does not show a pattern or a trend.

Figure S2.33: A graph of the size of bird eggs and month laid

Step 2 I can explain relationships between datasets and information

To explain relationships between variables, you must draw on your scientific knowledge and theoretical understandings. After identifying a relationship, the next step is to ask: Why is one variable affected by another variable in this way?

For example, in Figure S2.32 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.

Step 3 I can draw conclusions based on patterns in data and information

As scientists, we can draw conclusions based on the data that emerges from an investigation or study by:

a stating the relationship between the specific variables, based on the data

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 draw a conclusion.

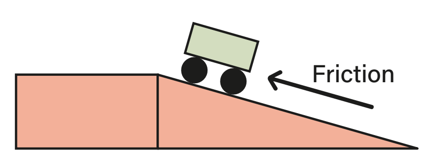


Figure S2.34: Investigating the effects of friction a State the relationship between the specific variables, based on the data.

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.

We have drawn a conclusive statement from the results. 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 S2.12 provides some more examples of drawing conclusions.

Table S2.12: Converting investigation results into broader conclusions

Relationship between variables	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 ring-tailed possums also increases.	Revegetation efforts increase native animal populations by restoring natural habitats.
The more water a barrel contains, the more people are required in order 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.

Step 4 I can assess data and information for accuracy, reliability and validity

This step is similar to Step 5 for 'Processing data and information', except we are focusing on the terminology used to assess data, rather than evaluating the investigation itself. The most challenging aspect of analysing information is determining the quality of the data itself – is it *high quality* or *low quality*? To do this, you must understand the terms *accuracy*, *reliability* and *validity*, and be able to connect them to the data you generate in an investigation.

Accuracy

Accuracy refers to how close your results are to the true value. When analysing information, the only way to know if it is accurate is to compare it to known theoretical values shown in your textbook or in scientific publications. You may have to conduct a little research to determine if the values are accurate or not.

Reliability

Data and information that is reliable means that we can trust that if we repeated the investigation, we could produce similar results. Reliable results indicate that the method used produces consistent and dependable results. **Reliability** considers both accuracy and precision.

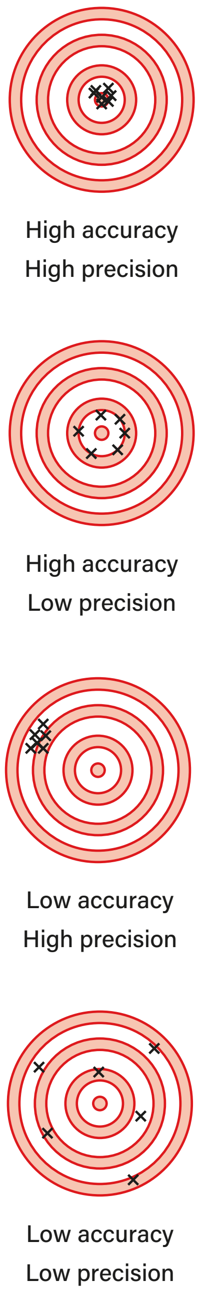


Figure S2.35: Accuracy and precision are *not* the same thing.

Precision is a measure of how similar values are to each other within a dataset. If you do multiple trials of the same test, you would expect the results to be mostly the same. If the values are very different from one trial to the next, your results are not precise.

However, if we conduct enough trials, the imprecise values will average out to a value that is near the true or accurate value. Therefore, the more precise your values are, and the more trials you do, the more reliable your results will be.

Validity

If an investigation is valid, it means the method measures what it is meant to measure. **Validity** allows us to make generalisations from our conclusion and to apply our learnings to other situations. It considers both accuracy of measurements and the control of variables.

In order for results to be valid, we must design a **fair test** that tests one variable at a time, while controlling all other variables that could affect the results. This is how we can determine a cause-and-effect relationship. If more than one variable changes, we cannot be sure what caused the effect, which means the test would not be considered fair and the results would not be valid.

By considering the accuracy of measurements, the precision of values within each dataset, and the method and materials used to isolate and control variables, you are able to assess data and information for reliability and validity.

Figure S2.36: Which of these containers has a volume closest to 50.0 mL? Measurements are always subject to errors.

Step 5 I can evaluate conclusions based on the quality of the data

The conclusion of any investigation usually has limitations. The limitations can stem from a range of factors, including the question being asked, the method used to investigate the question, or the quality of the data collected. Step 5 requires you to consider the data assessed in Step 4 towards identifying limitations of the conclusion.

As seen in Step 5 of 'Processing data and information', error bars can provide insight into the quality of the data. Consider Figure S2.27 on page 418. We might conclude that B is the highest, followed by A, D, E and C in descending order. However, this conclusion has limitations, because the quality of the data is low. We could conclude with confidence that B is the highest, but since the error bars for A, D, E and C all overlap each other, there is no way to know with certainty how A, C, D and E compare to each other.

We can also determine the quality of an individual dataset, which can also be used to evaluate a conclusion. For example, because the error bars are relatively small for B and E, the range of where the true value lies is more precise. This would allow conclusions to be made about the relationship between B and E with confidence, even though the data for A, C and D are of a lower quality.

Once a conclusion is evaluated and limitations are identified, extension work can be carried out that either modifies the method to improve the quality of results or asks new questions to strengthen the findings.

Problem-solving

Problems are questions about phenomena or issues that need to be answered. After asking scientific questions, scientists use problem-solving skills to help find answers that explain identified problems.

Step 1 I can propose solutions to familiar scientific problems

Familiar problems are problems that we have experienced before and have knowledge about. We can use our knowledge to suggest ways to solve these problems. To do this, we need to consider previous ways we have seen these problems solved. Ask yourself:

- When have I seen a problem like this before?
- How was this problem solved?

For example, imagine you notice that some lights in your house will all stop working when one of the bulbs blows.

- Where have I seen this before?

  In school, we tested different types of circuits to see how to keep single lights working when they are all in a circuit.
- How was this problem solved?

  Replacing the faulty bulbs in the series circuit allowed all of the lights to start working again.

This leads you to suggest figuring out which bulb has blown, so it can be replaced to complete the circuit.

Step 2 I can explain scientific problems and phenomena using cause-and-effect relationships

There is a link between scientific phenomena and their explanations. Once we have solved a problem that demonstrates this link, we can represent it by explaining the link between a cause and its effect.

When writing about these links, we structure our writing in a specific way. This structure allows us to show the link between the cause of a problem and its effect. This can be done in three sentences.

1. State what the problem is.
2. State what the cause of the problem is.
3. Link the two ideas together by stating how the problem can be solved.

Figure S2.37: Using knowledge from previous situations can help us to solve problems – like how we can get our light bulbs working again.

For example, after you have replaced the faulty light bulb, the rest of the bulbs work again when the lights are switched on.

You write an explanation for this problem:

The lights were not working because one bulb had blown. This meant that the series circuit did not form a closed loop. A circuit must be closed for electricity to flow through it. So, when the broken light bulb was replaced, electricity could flow through the circuit again, allowing all of the bulbs to transform electrical energy into light energy and light up.

Step 3 I can use given criteria to find solutions to scientific problems

When solving problems, we can apply criteria to help us find a solution. In a question, we may be given criteria to use. In other cases, we may need to identify which criteria we think will best help us solve the problem. Either way, we must use these criteria when working on a solution. With complicated problems, we may need to use research from secondary sources to help us understand and apply the criteria.

When working on a problem, ask yourself:

- What is the problem I need to solve?
- Have I been given criteria to use, and what are they?

If no criteria are given, then ask:

- Can I identify any criteria that can help me to solve the problem?

Once you have clearly identified any criteria, then ask:

- How will the criteria help me to solve the problem?

Now you can solve the problem using the criteria to inform your solution.

For example, a student was given the following problem to solve: Investigate transverse waves of increasing frequency by using materials to model their movement.

What is the problem I need to solve?

I need to design a way to demonstrate the movement of transverse waves of increasing frequency.

Have I been given criteria to use, and what are they?

I can see there are two criteria to use. The first criterion is the type of wave, and the second criterion is the frequency of the wave.

How will the criteria help me to solve it?

- *I can use my knowledge of transverse waves to select some materials that could move the way they are described, and pick the one that most clearly demonstrates the shape of the waves.*
- *I can change the speed at which I move the material to model the wave, as a way to model the change in frequency.*

Will secondary sources help me to identify anything I can test?

Research from a secondary source tells me that a transverse wave has particles that move perpendicular to the direction of the wave, meaning it has crests and troughs. So, it should look similar to ripples on water.

The student used some different materials to model transverse wave movement, and used the criteria to make the following conclusion:

After testing some model waves, it is clear that a skipping rope can effectively model transverse waves of different frequencies. When one end of the rope is secured to the pole and the other is moved up and down, the middle of the rope forms crests and troughs that get closer together as the speed of the up-and-down movement is increased.

Step 4 I can assess problem-solving strategies used to solve an identified problem

We need to select the most effective strategies when trying to solve a scientific problem. To do this, we should assess the available problem-solving options.

To assess the effectiveness of a strategy, we consider the benefits and limitations of each strategy, then judge which one is the most effective. For example, we could have the following problem:

I have three light bulbs that I want to place in a model house. I want each light to stay on independently, even if one bulb blows.

We can use two possible methods to wire the light bulbs:

- a series circuit with a singular path
- a parallel circuit with three distinct paths.

Table S2.13 shows how we can assess the benefits and limitations of each method.

Table S2.13: Assessing the best strategy to construct a circuit for three light bulbs

Strategy	Benefits	Limitations
Connect the bulbs in a series circuit	• The bulbs will light up when the light switch is turned on, as there will be a closed path. • The circuit requires fewer wires to construct.	If one bulb blows, the circuit will not be complete for any of the bulbs, so none will light up until the broken bulb is replaced.
Connect the bulbs in a parallel circuit	• The bulbs will light up when the light switch is turned on, as there will be three closed paths. • If one bulb blows, the other two bulbs will still have independent closed paths, so they will remain on.	The circuit requires more wires to construct.

Judgement:

Based on the benefits and limitations, the second strategy of using a parallel circuit will be the most effective when constructing the model house. This is because it allows all three bulbs to have their own closed path, so if one of them blows it will not impact the remaining two, and some lights will remain on even if one bulb blows.

Figure S2.38: Weighing up the benefits and limitations of various problem-solving strategies can help you to decide on the best strategy, such as which type of circuit to use when wiring household lights.

Step 5 I can evaluate scientific claims based on evidence

An important part of problem-solving is being able to evaluate claims that relate to scientific problems. To evaluate a scientific claim:

1 Identify the claim.
2 Identify the data relating to the claim.
3 Check that the data matches what the claim is saying.
4 Describe any benefits or limitations of the data.
5 Make a judgement on whether the data supports or refutes the claim.

For example, the claim 'Vaccines effectively prevent infectious diseases when 50 per cent of the population is vaccinated' can be evaluated using these criteria.

1 Identify the claim

The claim states that 50 per cent of a population needs to be vaccinated to prevent a disease.

2 Identify the data relating to the claim

Table S2.14 shows data on herd immunity from vaccinations.

Table S2.14: Data on herd immunity from vaccinations

Proportion of population vaccinated (%)	Susceptible individuals (%)	Risk of death from disease
0	100	High
50	50	Moderate
75	15	Low
90	5	Very low
95	<1	Negligible

3 Check that the data matches what the claim is saying.

This data shows that 50 per cent vaccination rates mean that 50 per cent of the population is still susceptible to the disease and at risk. This does not match the claim.

4 Describe any benefits or limitations relating to the data and claim.

Benefits:

- *The data shows that 50 per cent of the population will be protected when 50 per cent of the population is vaccinated and reduces the risk of deaths from diseases.*

Limitations:

- *Fifty per cent of the population is still susceptible to the disease.*
- *The data shows that 95 per cent of the population needs to be vaccinated to effectively prevent against diseases.*

Figure S2.39: Scientific claims must be supported by data.

5 Make a judgement on whether the data supports or does not support the claim.

The claim that 'Vaccines effectively prevent infectious diseases when 50 per cent of the population is vaccinated' is not supported by the data. An evidence-based claim would be 'Vaccines effectively prevent infectious diseases when 95 per cent of the population is vaccinated', as the data indicates that this results in less than 1 per cent of the population being susceptible to the disease.

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, depending on our audience.

Step 1 I can select appropriate ways to communicate information

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 S2.15 shows some examples of how to apply these questions to make your decision.

Table S2.15: 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
The effect of a catalyst on a chemical reaction	How adding a catalyst affects the rate of a chemical reaction	Scientific poster with text and diagrams
The electromagnetic spectrum	The frequency and uses of transverse waves from the electromagnetic spectrum	Scientific diagram with labels
Bacteria structure	What a bacteria cell looks like and contains	Scientific model

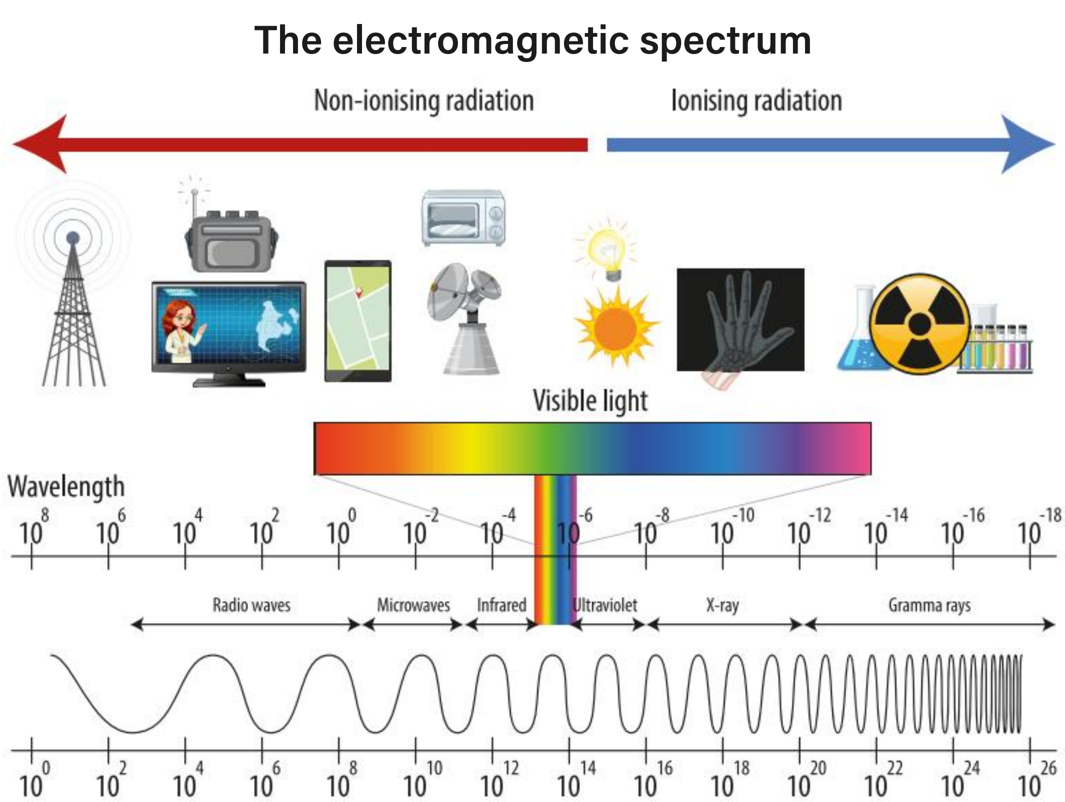


Figure S2.40: The electromagnetic spectrum can be represented using a labelled diagram.

Step 2 I can use digital technologies to organise and present 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 S2.16 provides a range of examples.

Figure S2.41: Digital technologies help us to lay out information neatly, ready for presenting.

Table S2.16: 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
The effect of a catalyst on a chemical reaction	Scientific poster with text and diagrams	Canva or slides to visually present information
The electromagnetic spectrum	Scientific diagrams with labels	Canva, slides or Lucidchart software to create a diagram with labels
Bacterial cell structure	Scientific model	Canva or Lucidchart software to create two-dimensional models

Step 3 I can construct a range of appropriate scientific presentations based on first-hand and second-hand data and information

After selecting a method of communication, and a digital technology to present it should you be using one, you can then look at how to construct a presentation. When considering how to present scientific information in a chosen format, 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 pages 433–45.

Step 4 I can present scientific findings using appropriate conventions for specific audiences

Now that you can determine different 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 S2.17 shows how the same information can be presented to two different audiences.

Table S2.17: Tailoring your message for different audiences

Age	Knowledge level	Idea	Communication
Eight-year-old children	Very limited	How to prevent a cold	Summarise simple steps to prevent pathogens from being transmitted.
Adults	High – biologists	How to prevent a cold	Present research on the pathogen and its transmission, including preventative measures.

We can then write a response for each audience. For the eight-year-olds, we could include the following text on a simple poster.

Around us, there are germs that can make us sick, with things like colds and the flu. We can help to stop people from becoming sick by getting a flu vaccine, washing our hands with soap and water for 20 seconds, covering our mouth with a tissue or our elbow when we cough, and staying home when we are sick!

The adult scientists would expect more sophisticated language, and the information could be displayed using specific diagrams and figures.

Viruses such as influenza and the common cold impact millions of individuals each year. To minimise the incidence of these diseases, strategies to prevent transmission via direct and indirect mechanisms should be implemented. Influenza vaccinations provide us with artificial acquired immunity, reducing the number of susceptible individuals in the population. Hand washing with soap and water removes viral pathogens from our hands, preventing ingestion. Covering mouths stops the transmission of the pathogen from saliva to other individuals, and isolating at home when unwell breaks the chain of transmission.

▲ **Figure S2.42:** A poster showing simple disease prevention techniques. This would be a suitable communication method to share ideas with younger audiences who have less scientific knowledge.

Step 5 I can evaluate scientific findings based on secondary evidence and arguments

Part of communicating information includes evaluating presented evidence and arguments. This requires reviewing available information and using it to make an informed judgement on the findings that have been presented by you or by another person.

To evaluate scientific findings:

1. Identify the relevant findings.
2. Gather information from valid secondary sources that relates to the presented findings.
3. Use this information to determine the benefits and limitations of the findings, including alternative explanations.
4. Make a judgement on the quality of the findings.

For example, scientists have been gathering and presenting information on the theory of evolution by natural selection since it was first published by Charles Darwin in 1859.

1 Identify the relevant findings.

The theory of evolution by natural selection is a scientific finding that explains how living things have evolved from a common ancestor over time in response to changes in the environment.

2 Gather information from valid secondary sources that relates to the presented findings.

Scientific articles from National Geographic, CSIRO and Nature present the following evidence for natural selection:

- *comparative anatomy and embryology*
- *biogeography*
- *the fossil record*
- *relative and absolute dating.*

3 Use this information to determine the benefits and limitations of the findings, including alternative explanations.

Alternative explanations for evolution include Lamarck's ideas on transformation, and Gould and Eldridge's idea of punctuated equilibrium, or rapid change followed by long periods of stagnation.

Benefits of Darwin's theory:

- *There are many different types of supporting evidence, all of which are published across reputable scientific sources by highly credentialled scientific authors.*
- *The theory accounts well for the diversification of life over time, since it began on Earth.*

Limitations:

- *There are other alternative suggestions, such as punctuated equilibrium, that are still being researched today which could also account for some of the evidence and findings.*
- *Some of the supporting evidence, such as the absolute dating of fossils, is not exact and can be subject to margins of error.*

Figure S2.43: Scientific findings should only be accepted if there is sufficient evidence supporting them, which is determined through evaluation.

4 Make a judgement on the quality of the findings.

Based on the overall evidence for, and acceptance of, the theory of evolution by natural selection, it can be suggested that natural selection is an evidence-based explanation.

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 terms

citation: a way of giving credit to a source, usually in the same text where the information appears

plagiarise: to copy someone else's work and present it as your own

Figure S3.1: Scientific writing is fundamental to science communication.

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.

Table S3.1: Investigation report sections matched to their working scientifically processes

Section	Process
Title	Questioning and predicting
Introduction ▪ Background ▪ Aim ▪ Hypothesis	Questioning and predicting Planning investigations
Risk assessment	Planning investigations
Materials	Planning investigations
Method	Conducting investigations
Results	Processing data and information
Discussion and conclusion	Analysing data and information
References	Communicating

The title is clear and uses plain language. Many scientists write their title as a research question.

To what extent do different modes of agitation affect the rate of a chemical reaction?

Set the scene. If there is scientific information or context for the investigation, summarise it here.

Introduction

Chemical reactions can occur at different rates, depending on the proportion of successful collisions between reacting particles in a given amount of time. Many factors can influence the frequency of successful collisions, such as temperature, concentration, surface area and the presence of a catalyst. Agitation of, or stirring, a reaction mixture is another factor that could have an impact on colliding particles. It would be interesting to compare how different ways of stirring a reaction mixture impact on the rate of a chemical reaction. This could inform what types of equipment are purchased for the laboratory and help in making methodical decisions for investigations in relation to efficiency.

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 ...'

Aim

To explore how different types of agitation – swirling once every 10 seconds, swirling continuously, and magnetic stirring – impact the rate of a chemical reaction.

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.

Hypothesis

If a chemical reaction is agitated to a greater extent and continuously during a reaction (magnetic stir), the reaction will occur at a higher rate than if it is only agitated manually and periodically throughout the reaction. This is because agitation increases the amount of collisions that occur between reactants in a given amount of time; therefore, more agitation will result in a higher proportion of successful collisions, increasing the rate of reaction.

List all materials and equipment with amounts and sizes as simple bullet points.

Materials

- *3 × 100 mL conical flasks with stopper and delivery tube*
- *3 × 20 mL 0.5 M HCl*
- *3 × 2 g clean magnesium strip*
- *water trough and inverted 100 mL measuring cylinder filled with water*
- *magnetic stir timer*

Method

1 *Measured 20 mL of 0.5 M HCl into each conical flask.*

2 *Inserted delivery tube under water and into inverted measuring cylinder.*

3 *Dropped one magnesium strip into the first conical flask and quickly replaced the stopper with tube already positioned under water. Started timer for 1 minute.*

4 *Every 10 seconds, recorded the total volume of gas collected in the inverted measuring cylinder, while swirling the flask for 2 seconds (starting at 10 seconds).*

5 *Repeated steps 2 to 4 for the other modes of agitation: swirling continuously and using a continuous magnetic stir.*

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.

Results

Table 1: *Effect of mode of agitation on rate of reaction*

Include recorded data such as the results table. Include any visual elements, such as photos or graphs, here.

Mode of agitation	Volume (mL) of gas collected every 10 seconds over 1 minute					
	10 s	20 s	30 s	40 s	50 s	60 s
Swirl every 10 seconds	0	5	12	18	21	23
Swirl continuously	8	17	28	36	41	47
Continuous magnetic stir	10	20	35	45	50	53

Discussion

As the results in Table 1 show, the mode of agitation that generated gas the fastest was the magnetic stir, with 53 mL of gas collected in 1 minute. Swirling continuously was the next-fastest mode, with 47 mL of gas collected, followed by swirling every 10 seconds, which collected 23 mL in 1 minute.

The results show a trend similar to the intensity and proportion of swirl time for each mode of agitation. Using the same mode of swirling, but for only 20 per cent of the time as compared to continuous swirling, saw very different results (a 25mL difference), indicating that the duration of agitation makes a significant difference in the rate of the reaction. Continuous stirring, whether swirling or magnetic, had similar results (a 6 mL difference), suggesting that continuous stirring, rather than intensity of stirring, has a more significant impact on the rate of reaction.

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.

One source of error is that the surface area of the magnesium strips was observed to be inconsistent. Although they were 2 g for each mode, the strip for the magnetic stir was longer than the others. This means it had more surface area, which would have led to a higher reaction rate independent of the agitation because, according to collision theory, increased surface area increases reaction rate. This would have caused the amount of gas that was collected to be higher than it would have been had the magnesium's surface area matched the others.

The method could be improved by replacing magnesium with a reactant that has a surface area that is easier to control, such as a powdered substance. Carrying out multiple trials with magnesium would also minimise this error by averaging out the inconsistencies in surface area.

Identify any potential errors here and suggest improvements to try to control them.

Conclusion

The results of this investigation show that the mode of agitation does impact the rate of a chemical reaction, with the duration of agitation playing a larger

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.

role in reaction rate than the intensity of agitation. The investigation supported the hypothesis that if this reaction is stirred continuously using a magnetic stirrer, it will react at a higher rate in the first minute than if it is only swirled once every 10 seconds. This is due to a higher proportion of successful collisions occurring in a given amount of time.

References show the source of any information you used that was not your own, including for the background.

References

Constant A, Cashmere R, Fricker A, Herron C, Ley J and Saffin P, 2025, Good Science NSW Stage 5, 2nd ed. Matilda Education.

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 to 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.

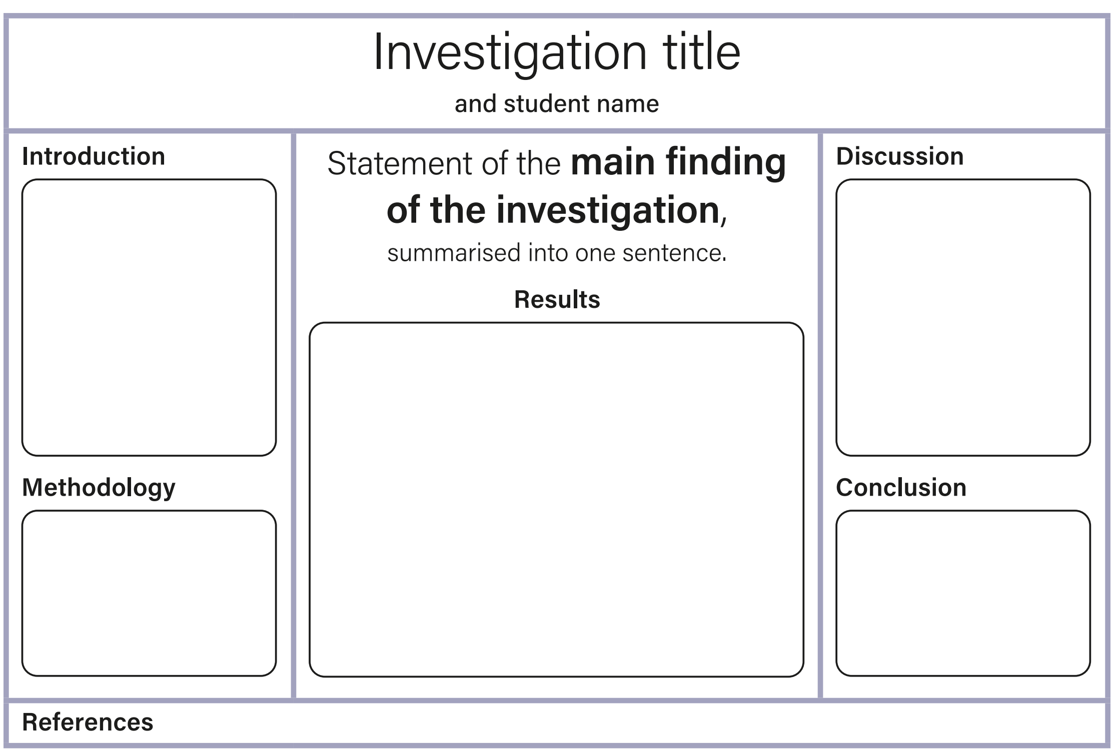


Figure S3.3 gives an example of how we might present, in poster form, the findings from our investigation report on how different modes of agitation affect the rate of a chemical reaction. We could add visual interest by adding sketches of flasks.

To what extent do different modes of agitation affect the rate of a chemical reaction?

Introduction

Chemical reactions can occur at different rates, depending on the proportion of successful collisions between reacting particles in a given amount of time. Many factors can influence the frequency of successful collisions, such as temperature, concentration, surface area and the presence of a catalyst. Agitation of, or stirring, a reaction mixture is another factor that could have an impact on colliding particles. It would be interesting to compare how different ways of stirring a reaction mixture impact on the rate of a chemical reaction. This could inform what types of equipment are purchased for the laboratory and help in making methodical decisions for investigations in relation to efficiency.

Methodology

Within this investigation, 20 mL of 0.5 M HCl was placed into three conical flasks. Strips of magnesium metal were placed into each flask, and the contents were then agitated at different intervals: once every 10 seconds; hand swirled continuously; and agitated quickly using a magnetic stirrer. All flasks contained the same amount of magnesium and acid. The rate of gas production was measured from each flask in an inverted measuring cylinder.

The mode of agitation correlates with the rate of reaction.

Results data

Table 1: Effect of mode of agitation on rate of reaction

Mode of agitation	Volume (mL) of gas collected every 10 seconds over 1 minute					
	10 s	20 s	30 s	40 s	50 s	60 s
Swirl every 10 seconds	0	5	12	18	21	23
Swirl continuously	8	17	28	36	41	47
Continuous magnetic stir	10	20	35	45	50	53

Discussion

As the results in Table 1 show, the mode of agitation that generated gas the fastest was the magnetic stir, with 53 mL of gas collected in 1 minute. Swirling continuously was the next-fastest mode, with 47 mL of gas collected, followed by swirling every 10 seconds, which collected 23 mL in 1 minute.

One source of error is that the surface area of the magnesium strips was observed to be inconsistent. Although they were 2 g for each mode, the strip for the magnetic stir was longer than the others. This means it had more surface area, which would have led to a higher reaction rate independent of the agitation because, according to collision theory, increased surface area increases reaction rate. This would have caused the amount of gas that was collected to be higher than it would have been had the magnesium's surface area matched the others.

The method could be improved by replacing magnesium with a reactant that has a surface area that is easier to control, such as a powdered substance. Carrying out multiple trials with magnesium would also minimise this error by averaging out the inconsistencies in surface area.

Conclusion

The results of this investigation show that the mode of agitation does impact the rate of a chemical reaction, with the duration of agitation playing a larger role in reaction rate than the intensity of agitation. The investigation supported the hypothesis that if this reaction is stirred continuously using a magnetic stirrer, it will react at a higher rate in the first minute than if it is swirled only once every 10 seconds. This is due to a higher proportion of successful collisions occurring in a given amount of time.

Reference: *Constant A, Cashmere R, Fricker A, Herron C, Ley J and Saffin P, 2025, Good Science NSW Stage 5, 2nd ed. Matilda Education.*

Figure S3.3: A simple scientific poster

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 443 for more information.

Figure S3.4: High-quality scientific articles can be reviewed by other scientists and published in scientific journals.

Figure S3.5 provides an example framework for a science article.

Figure S3.5: The structure of a science article on the effect of agitation on the rate of a chemical reaction

Heading

The effect of agitation on the rate of a chemical reaction

Author

Bailey Chang

Abstract

Abstract

A review of an investigation into chemical reaction rates was conducted. The investigation and method were studied and analysed to determine the effect of agitation on reaction time. The study found that increased agitation of the chemical solution correlated with increased rate of reaction – 53 mL over 60 seconds with continuous agitation, compared to 23 mL with agitation every 10 seconds. Further investigation into similar studies could assist in supporting this hypothesis.

Introduction

Introduction

Chemical reactions can occur at different rates, depending on the proportion of successful collisions between reacting particles in a given amount of time. Many factors can influence the frequency of successful collisions, such as temperature, concentration, surface area and the presence of a catalyst. Agitation of, or stirring, a reaction mixture is a factor that directly impacts the rate of colliding particles in a reaction. By agitating particles, the amount of successful collisions between particles is increased; therefore, the overall rate of reaction is increased. This could inform what types of equipment are purchased for the laboratory and help in making methodical decisions for investigations in relation to efficiency.

Method

Within this investigation, 20 mL of 0.5 M HCl was placed into three conical flasks. Strips of magnesium metal were placed into each flask, and the contents were then agitated at different intervals: once every 10 seconds; hand swirled continuously; and agitated consistently using a magnetic stirrer. All flasks contained the same amount of magnesium and acid. The rate of gas production was measured from each flask in an inverted measuring cylinder.

Method

Results

As the results in Table 1 show, the mode of agitation correlates with the rate of reaction. More consistent agitation led to a greater rate of reaction.

Results

Table 1: Effect of mode of agitation on rate of reaction

Mode of agitation	Volume (mL) of gas collected every 10 seconds over 1 minute					
	10 s	20 s	30 s	40 s	50 s	60 s
Swirl every 10 seconds	0	5	12	18	21	23
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Discussion

As the results in Table 1 show, the mode of agitation that generated gas the fastest was the magnetic stir, with 53 mL of gas collected in 1 minute. Swirling continuously was the next-fastest mode, with 47 mL of gas collected, followed by swirling every 10 seconds, which collected 23 mL in 1 minute.

Discussion

The results show a trend similar to the intensity and proportion of swirl time for each mode of agitation. Using the same mode of swirling, but for only 20 per cent of the time as compared to continuous swirling, saw very different results (a 25 mL difference), indicating that the duration of agitation makes a significant difference in the rate of the reaction. Continuous stirring, whether swirling or magnetic, had similar results (a 6 mL difference), suggesting that continuous stirring, rather than intensity of stirring, has a more significant impact on the rate of reaction.

One source of error is that the surface area of the magnesium strips was observed to be inconsistent. Although they were 2 g for each mode, the strip for the magnetic stir was longer than the others. This means it had more surface area, which would have led to a higher reaction rate independent of the agitation because, according to collision theory, increased surface area increases reaction rate. This would have caused the amount of gas that was collected to be higher than it would have been had the magnesium's surface area matched the others.

The method could be improved by replacing magnesium with a reactant that has a surface area that is easier to control, such as a powdered substance. Carrying out multiple trials with magnesium would also minimise this error by averaging out the inconsistencies in surface area.

References

Constant A, Cashmere R, Fricker A, Herron C, Ley J and Saffin P, 2025, *Good Science NSW Stage 5*, 2nd ed. Matilda Education.

References

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.

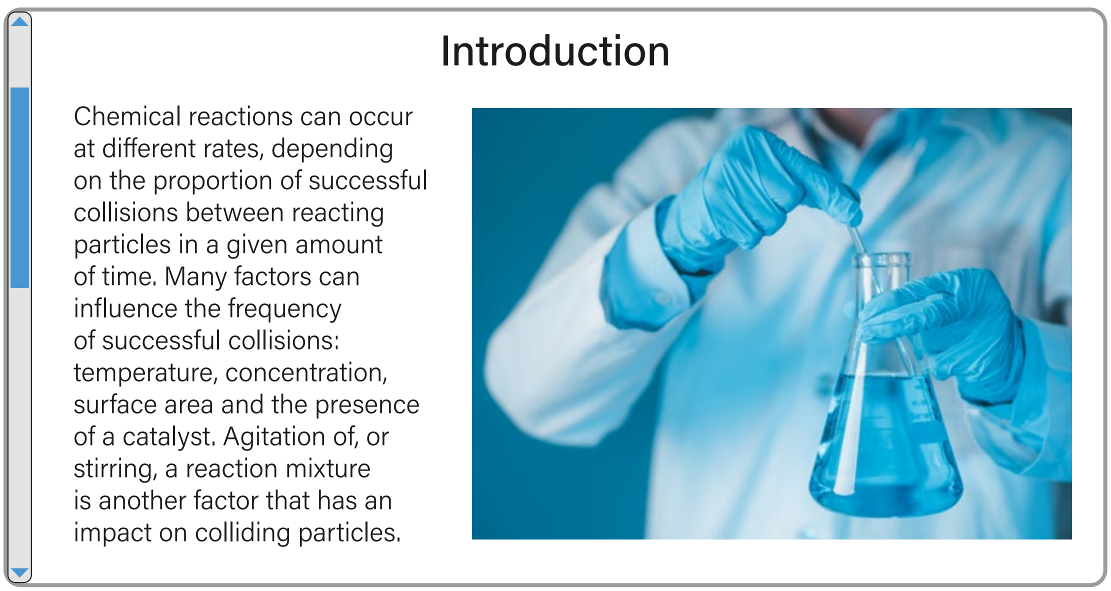


Figure S3.6: An example of a slide layout for a scientific presentation.

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 bacteria. 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 bacteria and its structures and components.

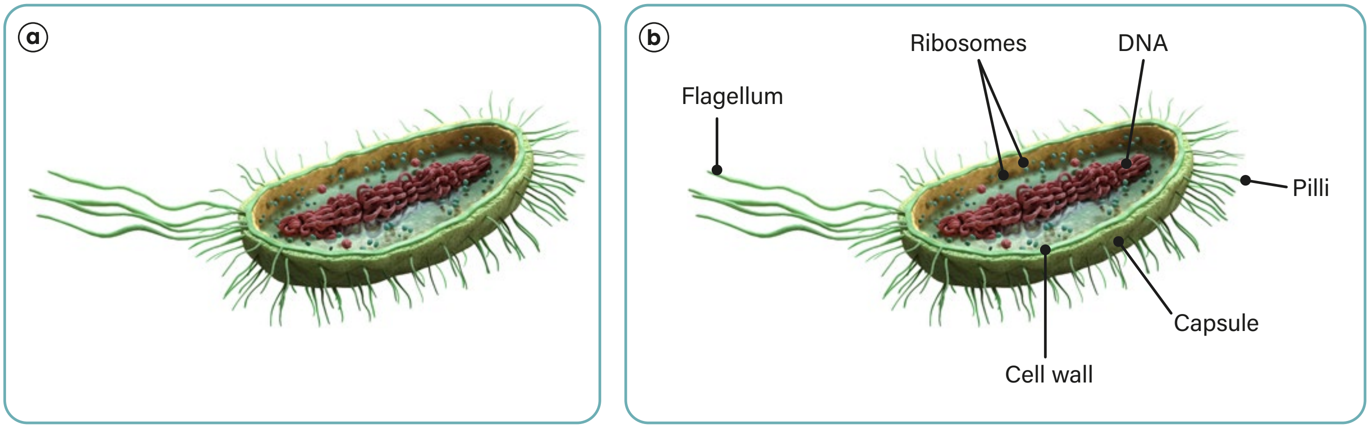


Figure S3.7: (a) A model of a bacteria that is missing labels; (b) an improved model of a bacteria, including labels

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 (Figure S3.8).

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?

Figure S3.8: The CRAAP test

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 following two sources of information about water.

Table S3.2 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: Research sources for the topic of water

Source	mea.digital/gsnsw4_9_3	Pass?	mea.digital/gsnsw4_9_4	Pass?
Webpage name	Scientific topics: Water		Dihydrogen Monoxide (DHMO) Research Division	
Currency	Last updated: 7 June 2023 – current	☑	Last updated: 13 June 2024 – current	☑
Relevance	Provides information on the distribution and use of water in Australia – highly relevant	☑	Provides information on some uses of water and the dangers of the chemical compound water – slightly relevant	☑
Authority	Geoscience Australia – a government department focused on water research – good authority	☑	Tom Way/DHMO organisation – no listed qualifications – poor authority	☒
Accuracy	Similar information can be found across multiple government and third-party websites – highly accurate	☑	Very few other sites talk about the listed dangers of DHMO – not accurate	☒
Purpose	To educate Australians on where water is and how it is used. Not biased as it is based on 13 June scientific research performed by the government – good purpose	☑	Dihydrogen monoxide is just water. The site shows that fear can be promoted by using scary-sounding technical terms and linking to outdated reports or biased articles. The site's purpose is to provide inaccurate information.	☒

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 fulfil the CRAAP test
- specific search areas such as Google Scholar, which will show 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 S3.9: There are many places to access valid sources of information, such as Google Scholar. 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, or adding a **citation**, 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 collect 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 <u>underlined</u>; or article title in quote marks, with details of the journal
4. the title of the webpage 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 book and a journal article.

Constant A, Cashmere R, Fricker A, Herron C, Ley J and Saffin P, 2025, *Good Science NSW Stage 5*, 2nd ed. Matilda Education.

Schmitz G, 2005, 'What Is a Reaction Rate?,' *Journal of Chemical Education*, Volume 82, Issue 7, accessed 28 September 2024, https://pubs.acs.org/doi/10.1021/ed082p1091.

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:

Topic sentence to introduce the main idea of the paragraph.

Explanation and elaboration of the idea.

Evidence, including direct references to the source that supports the idea.

Linking sentence to the next paragraph or back to the main idea of the essay.

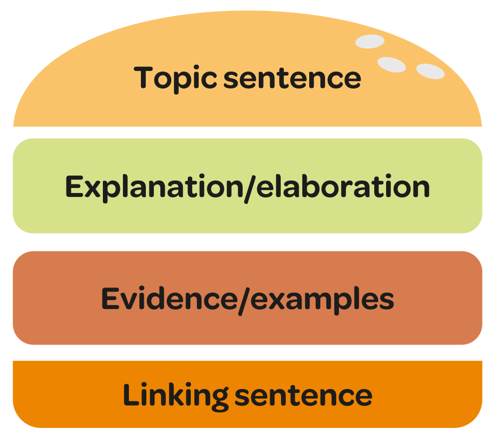


Figure S3.10: Each TEEL paragraph should build on the topic and link to the next idea or the essay as a whole.

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 three body paragraphs should provide a new reason why your position is valid.

S4 Scientific numeracy

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

percentage error measures how close the experimental value of an investigation is to the theoretical or true value

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

'Scientific numeracy' means having the knowledge and skills to apply mathematics to your science studies and understanding the science you see in everyday life. It involves using mathematical knowledge to understand, interpret and assess scientific knowledge and information. We encourage you to look at the *Science 7–10 Data Book* to help you to apply this knowledge to scientific concepts you are working on.

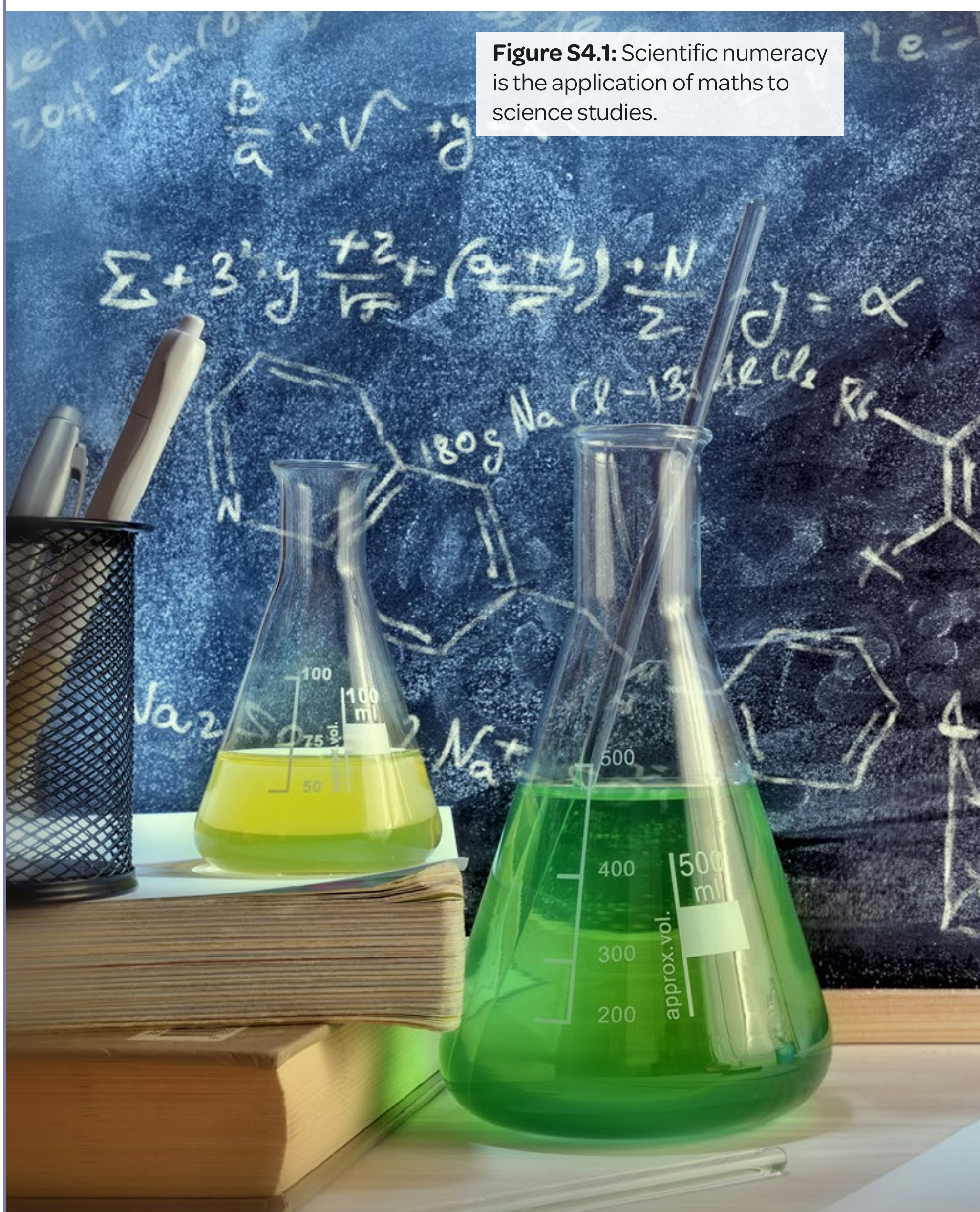


Figure S4.1: Scientific numeracy is the application of maths to science studies.

Units of measurement

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 (°C) for temperature, rather than the SI unit of kelvin (K). (Note that 1 ° Celsius is equivalent to +274.15 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 their unit.

Table S4.1: Some common measurements, symbols and units

Measurement	Symbol*	Commonly used unit at this level
Length or distance	l/d	metre (m)*
Time	t	second (s)*
Speed or velocity	v	metres per second (m s^{-1})*
Mass	m	gram (g), kilogram (kg)*
Volume	V	millilitre (mL), cubic metre (m^3)*
Density	ρ	grams per millilitre (g mL^{-1})
Temperature	T	degrees Celsius (°C)
Force	F	newton (N)
Acceleration	a	metres per second squared (m s^{-2})*
Energy	E	joule (J)
Number of …	N	no units

*SI unit. Source: *Science 7–10 Data Book.* NSW Education Standards Authority.

Tip 1: **Capitalisation matters**. 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 kg to N 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 × 1000 = 2500 **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 (×).
- 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 ÷ 1000 = 0.15 **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 (÷).
- 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

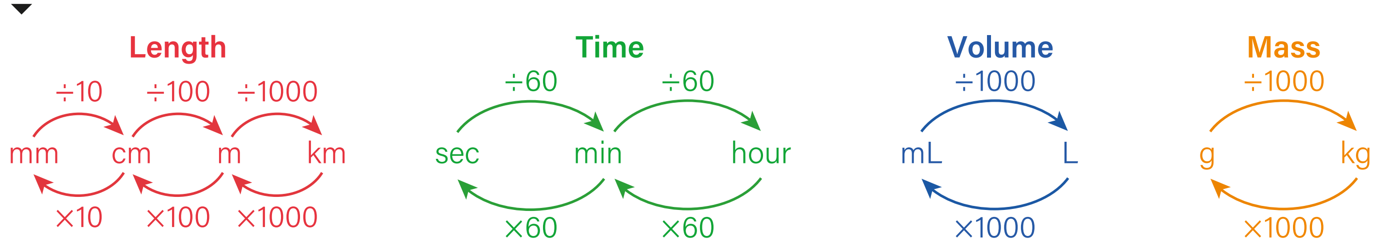
1 (hour) × 60 (minutes) × 60 (seconds) = 3600 **s**

Answer: 4 × 3600 = 14 400 **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* (×). 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**).

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.

Figure S4.2: Conversion charts for length, time, volume and mass



Worked example 2: Converting between units using conversion charts

1 Convert 250 metres to kilometres.
Hint: you are converting to a *larger unit*; therefore, you need to *divide*.
The conversion from the chart is to divide by 1000:
250 ÷ 1000 = 0.25 km

2 Convert 40 kilograms to grams.
Hint: you are converting to a *smaller unit*; therefore, you need to *multiply*.
The conversion from the chart is to multiply by 1000:
40 × 1000 = 40 000 g

3 Convert: 7200 seconds to hours:
The conversion for 1 second to 1 minute is to divide by 60, then divide by 60 again to get hours.
7200 ÷ 60 = 120 mins ÷ 60 = 2 hrs

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 (× 2).

To identify a ratio, first count the total of each category and write the two totals (for example, '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 ÷ 2 = 3 and 2 ÷ 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.

Water (H_2O)

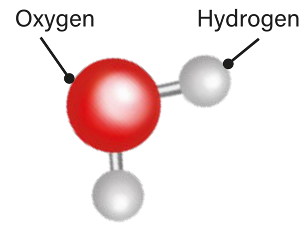


Figure S4.4: This model of water clearly shows the 2:1 ratio of hydrogen to oxygen.

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.

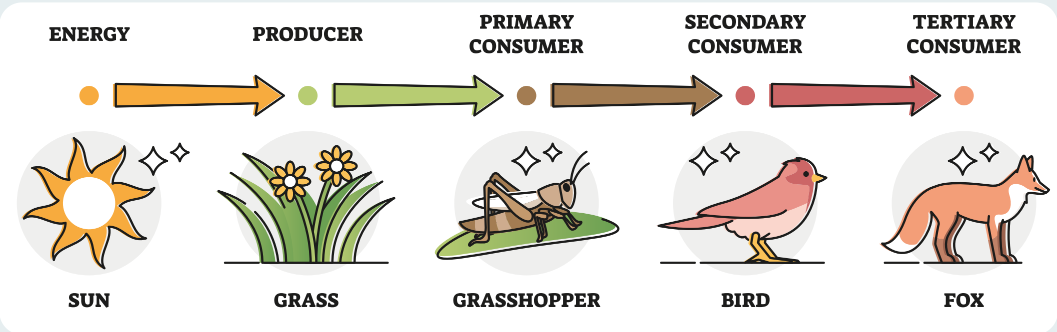


Figure S4.5: Energy moves up a food chain.

Question: How much energy would a grasshopper need to store to provide a bird with 630 joules of energy?

630 x 10 = 6300 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% of the grasshopper's energy store passes up the food chain to the bird.
- This 10% 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 of measuring 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 ÷ 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 Percentage = 0.3 × 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 km^3 of fresh water on Earth, but only 6 225 000 km^3 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 km^3 The whole = total fresh water = 41 500 000 km^3	Identify and label the values given in the question.
3 $\text{Percentage} = \frac{6\,225\,000}{41\,500\,000} \times 100$ Percentage = 0.15 x 100 = 15%	Substitute the given values into the formula. You might need to use your calculator.
4 Answer: Available freshwater is 15%	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 = $\frac{15\,960}{28\,000} \times 100\%$ Efficiency = 0.57 x 100 = 57%	Substitute the given values into the formula. You might need to use your calculator to work this out.
5 Answer: The efficiency of the hairdryer is 57%	The percentage symbol (%) must always accompany a percentage value.

Percentage error

Percentage error tells you how close the experimental value of an investigation is to the theoretical or true value. In this case, the 'part' that you are using to determine the percentage is the difference between the experimental value and the theoretical value. The 'whole' is the true value.

$$\%\ \text{error} = \frac{\text{experimental value} - \text{true value}}{\text{true value}} \times 100$$

The closer your percentage is to zero, the more accurate your results.

Worked example 8: Calculating percentage error

The volume of carbon dioxide collected during an experiment was measured to be 56.5 mL; however, the calculations predicted that 62.3 mL should form. Calculate the percentage error of these experimental results:

1 Identify the formula for calculating percentage error.

$$\%\ \text{error} = \frac{\text{experimental value} - \text{true value}}{\text{true value}} \times 100$$

2 Substitute the known values into the formula.

$$\%\ \text{error} = \frac{56.5 - 62.3}{62.3} \times 100$$

3 Solve for the percentage error.

$$\%\ \text{error} = \frac{-5.8}{62.3} \times 100 = -9.3\%$$

Note: The percentage error is negative, which indicates the experimental value is less than the true value. Sometimes the negative is ignored, so percentage error is always positive.

Normally, you will not see percentages that are higher than 100, but since percentage error is a comparison, it is possible for the percentage error to go above 100. However, this may indicate very low-quality results. For example, if 150 mL of carbon dioxide was collected in the worked example above, the percentage error would be 141. This tells us not only that more than double the amount of gas was collected than expected, but also that major sources of error are likely present in the method.

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 × 10 × 10. The '3' 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 × 10 × 10 × 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 × 10 × 10 × 10 × 10 × 10 × 10 × 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 9 and 10, we will explore writing large and small numbers in scientific notation.

Worked example 9: 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.

It becomes 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)

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 10: 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:

0.0.0.0.0.0.9.8

- 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:

3.2×10^{4} = move the decimal point 4 places to the right = 32 000

3.2×10^{-4} = move the decimal point 4 places to the left = 0.00032

Table S4.4 compares several examples of decimal notation to scientific notation.

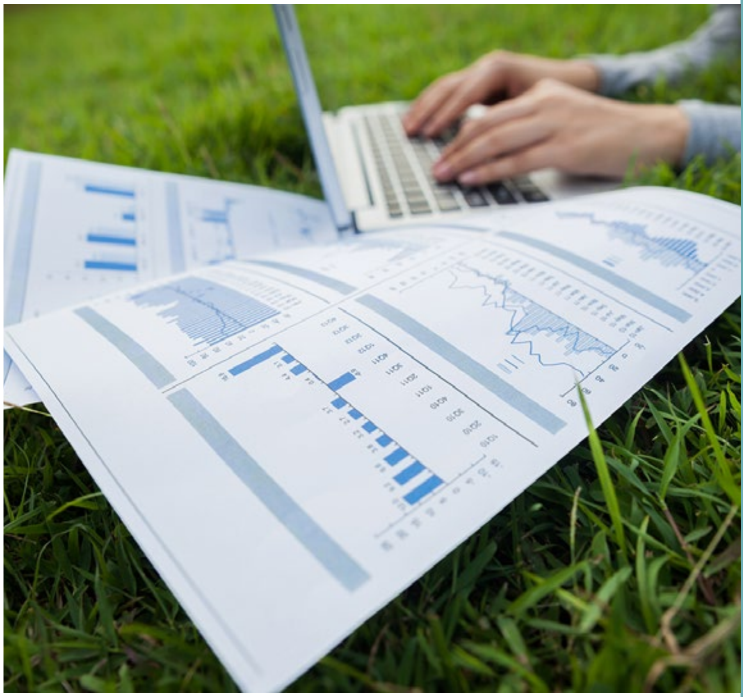
Table S4.4: Comparing decimal and scientific notation

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}
0.004 323 7	4.3237×10^{-3}
−23 000	-2.3×10^{4}
5 830 000 000	5.83×10^{9}
0.9	9×10^{-1}
0.000 000 0351	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 per cent in 2018, 24 per cent in 2019, 32 per cent in 2020, 45 per cent in 2021 and 60 per cent in 2020. 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 per cent).
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 a 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, the percentage of cars sold with airbags is increasing over time. This is a positive trend.

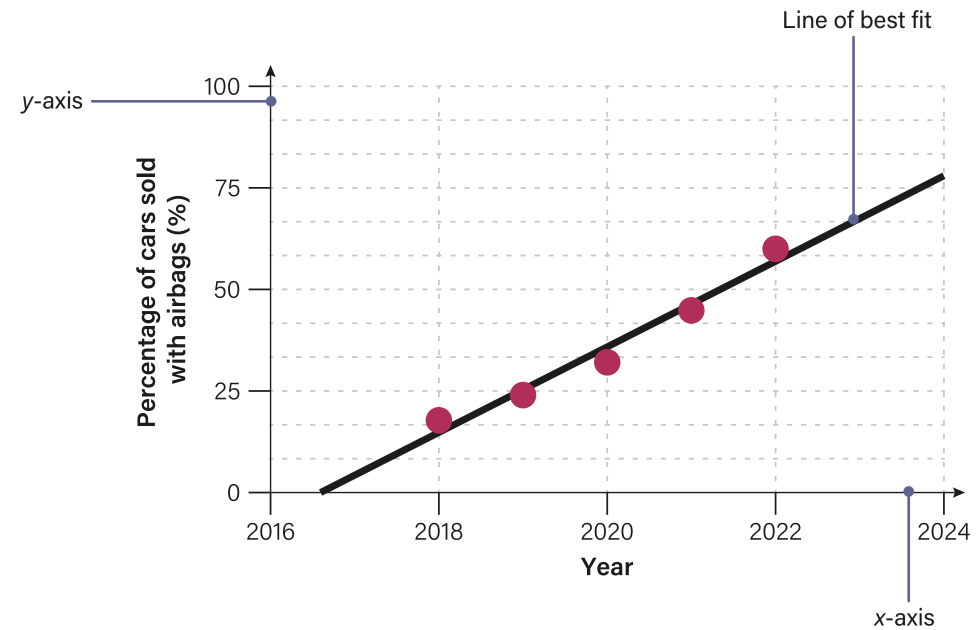


Figure S4.8: Percentage of cars sold with airbags (%) per year, 2016–24

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.

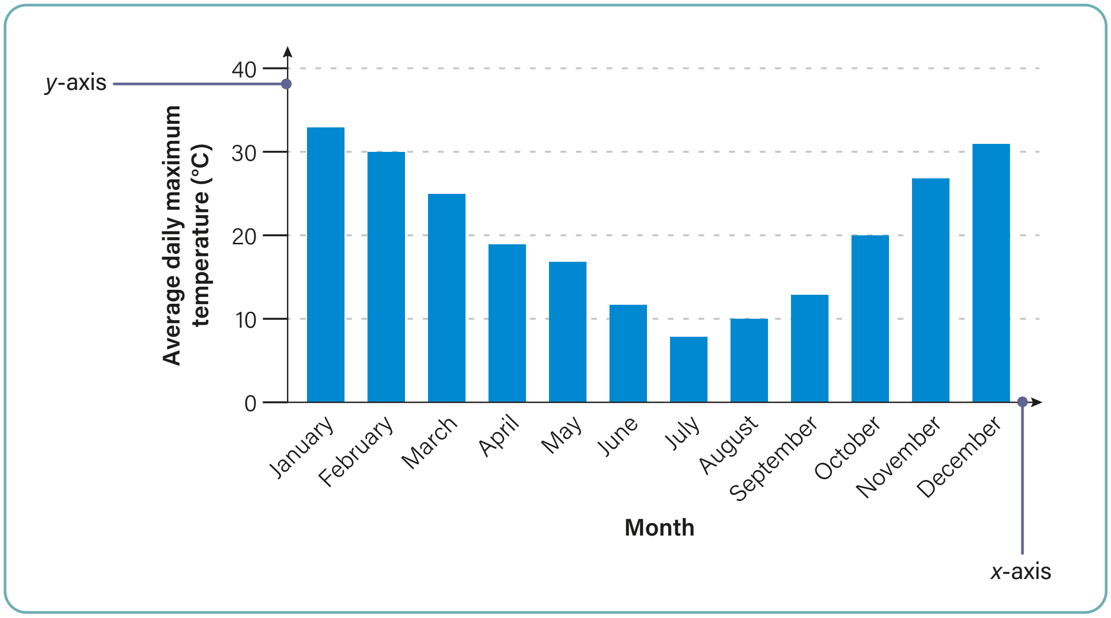


Figure S4.9: Average daily maximum temperature across month of the year in City X, 2024

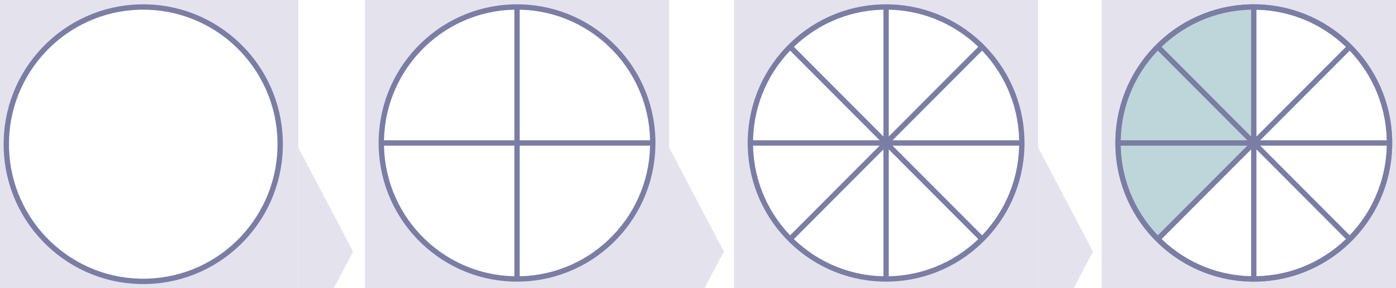
Making pie charts

A pie chart is a visual representation of parts of a whole. The 'pie' is a circle where each 'piece' represents a fraction or a 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 such as 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: Pie charts are used to visually display the percentage of parts that make up a whole, such as this graphic representation of the percentages of different fruits consumed weekly by a household.



Draw a circle.

Then, draw two straight lines through the circle to divide it into 4 equal parts.

These are 25% each.

Next, draw two more diagonal lines that divide each of the 4 pieces into 2 equal parts, to make 8 equal pieces in total.

These are 12.5% each.

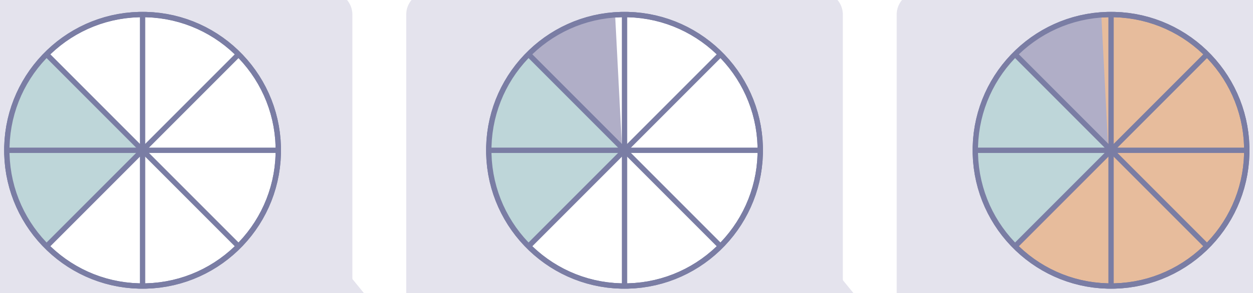
Next, shade the pieces as needed to estimate the size each piece should be for your pie chart.

For example, a pie chart with two parts, 37.5% (shaded) and 62.5% (unshaded), would look like the circle shown.

Figure S4.11: How to create a simple pie chart using estimates

Figure S4.12: Representing three amounts in a pie chart using estimates

Let's 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 × 12.5% = 62.5). So, shade 5 more pieces, plus the tiny bit or 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.

This is one way to estimate the size of the pieces of a pie chart when drawing by hand. Explore other ways to draw pie charts by hand, such as by using 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 the pieces of your pie chart as exact as possible.

Worked example 11: Drawing pie charts

To create each sector, first add up the total distance. In our investigation results, Table S2.9 on page 413, the total distance all three wheels travelled is 70 cm. 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
Compact disc	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.

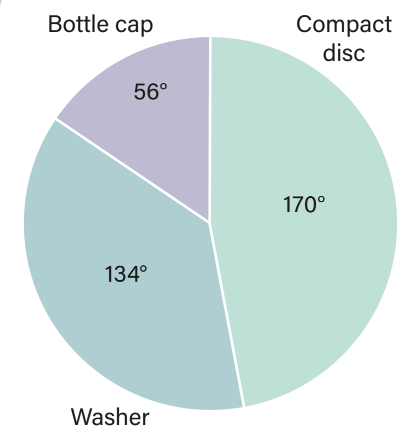


Figure S4.13: The finished chart clearly shows each part of the whole distance.

Using formulas to determine an unknown value

Mathematical formulas are used to show the 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:

$$\rho = \frac{m}{V}$$

Worked example 12 will help you to understand how to use this formula to determine an unknown value.

Worked example 12: Choosing a formula to determine an unknown value

You pour a cup of tea and measure a volume of 30 mL of honey into it. Your tea now weighs (has a mass of) 42 g more than before the honey was added. What is the density of the honey?

1 mass, $m = 42$ g
volume, $V = 30$ mL
density, $\rho = ?$

- Collect the information you have been given:
  You know the volume of honey and the mass of the tea. You don't know the density of the honey. That is what you are trying to work out.

2 $\rho = \frac{m}{V}$

- Choose the formula that allows you to use the information you have collected. The formula is for density.

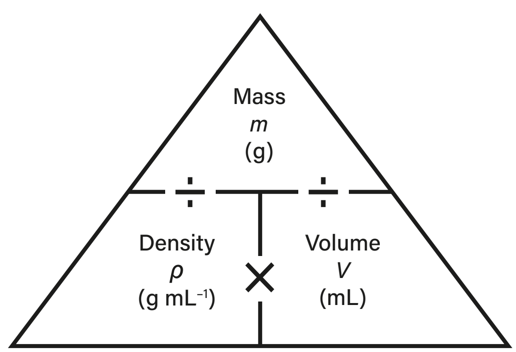
3 $\rho = \frac{42}{30}$

- Calculate the density of the honey by substituting the known values into the formula. (You can use your calculator.)

4 Answer: $\rho = 1.4$ **g mL^{-1}**

- $42 \div 30 = 1.4$
- 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 $m = \rho \times V$. If you know the mass and density, the formula to solve for volume is $V = m/\rho$.



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 precisely, which includes knowing your equipment and how to use it. In this section, we will familiarise ourselves with common equipment.

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

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.

Protective equipment: Wear safety glasses, gloves and a lab 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.

For more information on safety in science, see *Good Science NSW Stage 4*, pages 14–15.

Figure S5.1: Working with chemicals requires following safety information and wearing personal protective equipment (PPE).

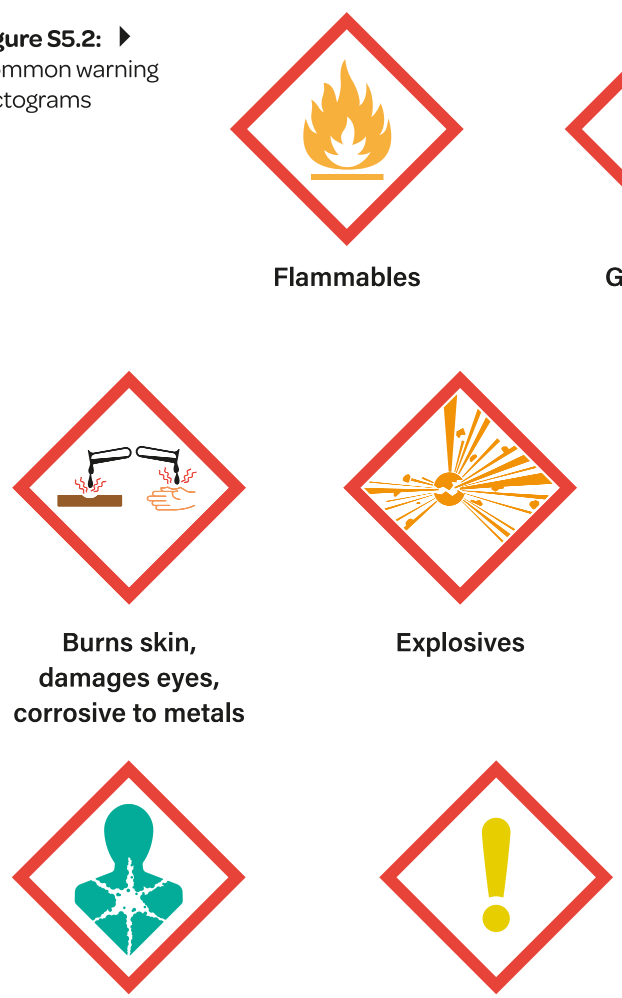
Pictograms

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 the 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.

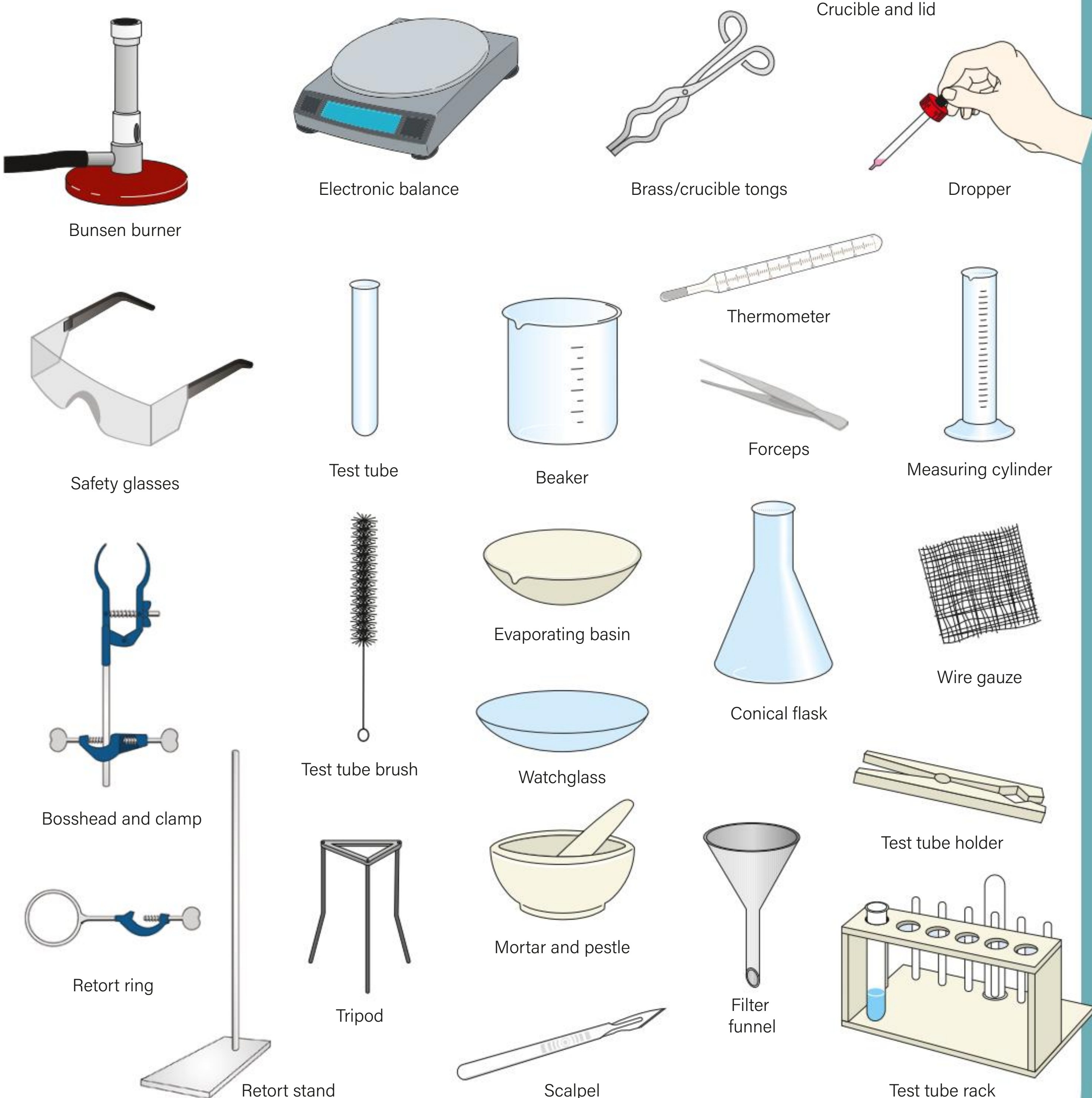
Laboratory equipment

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 items of equipment are shown here.

Note: You should already be familiar with Bunsen burner use and safety. For a refresher, see *Good Science NSW Stage 4*, page 15.

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 (°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.

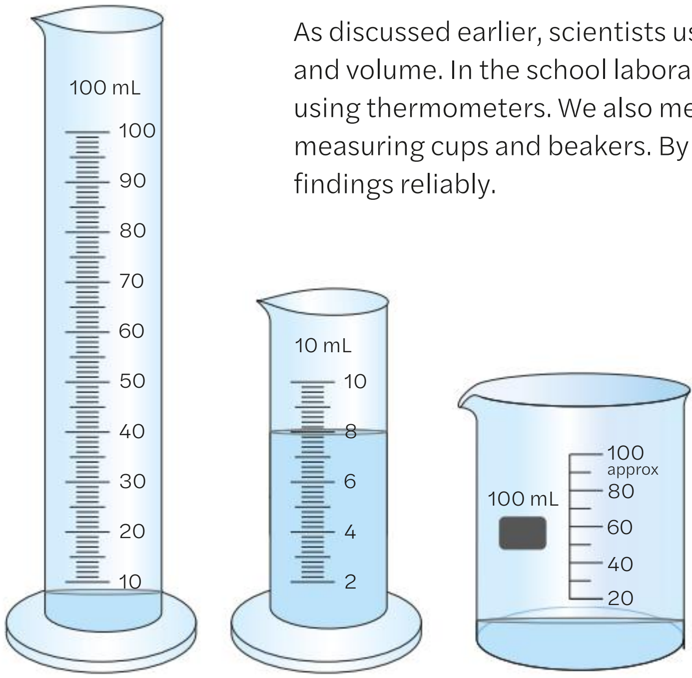


Figure S5.5: When measuring 8.0 mL, use the smallest measuring cylinder that can hold the required amount.

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. Beakers are typically used when volumes are approximate, while measuring cylinders are used when precision (the exact amount) matters.

When selecting a measuring cylinder, always use the smallest 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, rather than a 100 mL one, 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 estimated and is therefore uncertain.

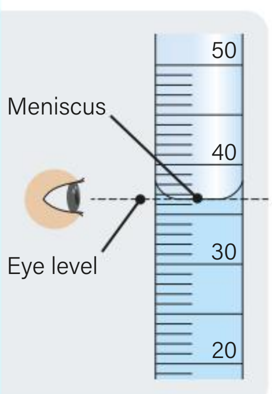
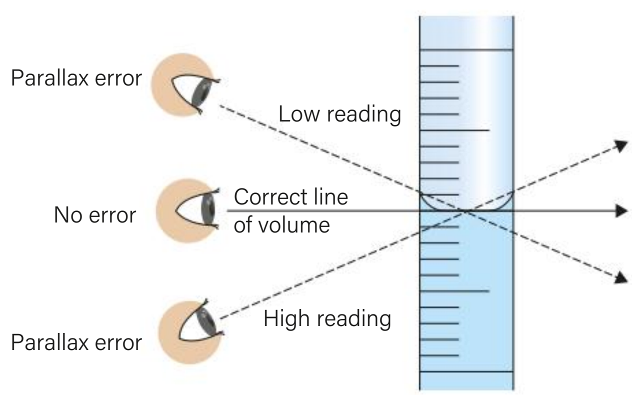


Figure S5.6: Take volume readings at eye level.

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.



Measuring cylinder (zero at the bottom)

Figure S5.7: To avoid parallax error, place yourself at the appropriate level. This takes practice.

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.

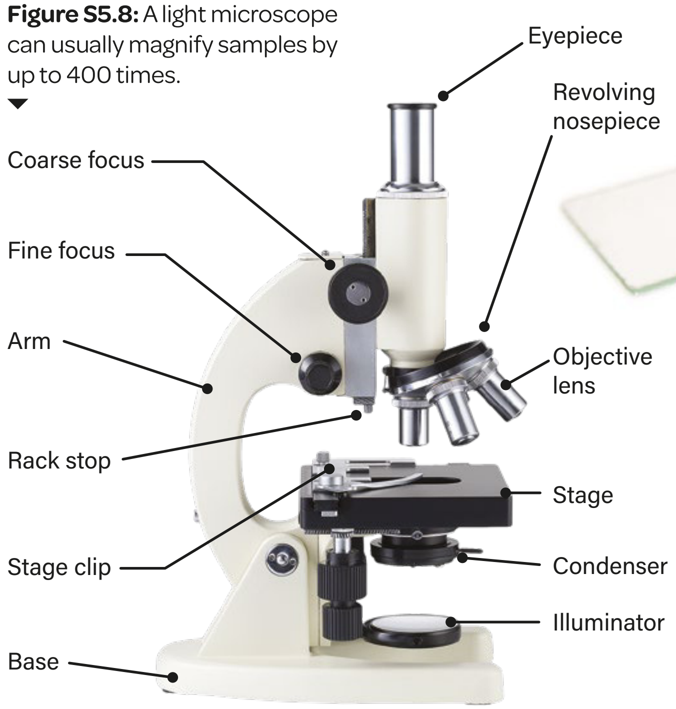


Figure S5.9: Microscope slides are usually made of glass and are very fragile. Treat them carefully.

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 its 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	Working scientifically process	Syllabus outcome	Working scientifically content focus	Teacher demon-stration
Focus Area 1: Energy					
1.1	Galileo's pendulum	Observing	SC5-WS-01	Using observations and measurements to answer questions	
1.2	Energy efficiency of bouncing balls	Problem-solving	SC5-WS-07	Explaining scientific problems and phenomena using cause-and-effect relationships	
1.6A	Modelling a simple circuit	Observing	SC5-WS-01	Making inferences from observations	
1.6B	Conductors and insulators	Observing	SC5-WS-01	Recording observations and measurements accurately	
1.7	Exploring Ohm's law	Conducting investigations	SC5-WS-04	Conducting first-hand investigations and accurately recording data	
1.8	Series and parallel circuits	Conducting investigations	SC5-WS-04	Using scientific equipment to conduct investigations	
1.9	Comparing energy in appliances	Problem-solving	SC5-WS-07	Using given criteria to find solutions to scientific problems	
1.10	Insulation and heat transfer	Problem-solving	SC5-WS-07	Suggesting solutions to familiar scientific problems	
1.11	Atmospheric convection and inversion layer	Problem-solving	SC5-WS-07	Explaining scientific problems and phenomena using cause-and-effect relationships	✓
Focus Area 2: Disease					
2.1A	Sensory receptors	Communicating	SC5-WS-08	Using digital technologies to present data	
2.1B	Reaction time	Communicating	SC5-WS-08	Presenting scientific findings	
2.3	Sheep brain dissection	Communicating	SC5-WS-08	Constructing presentations on findings	
2.5	Cardiovascular disease in Australia	Analysing data and information	SC5-WS-06	Assessing second-hand data for accuracy, reliability and validity	
2.6A	Modelling direct disease transmission	Communicating	SC5-WS-08	Using digital technologies to present information	
2.6B	Modelling indirect disease transmission	Communicating	SC5-WS-08	Presenting scientific findings	
2.9	The contagion game	Analysing data and information	SC5-WS-06	Drawing conclusions based on patterns in data	
2.13	Infectious diseases and vaccination: data analysis	Analysing data and information	SC5-WS-06	Describing trends from data	

Investigation number	Investigation title	Working scientifically process	Syllabus outcome	Working scientifically content focus	Teacher demon-stration
Focus Area 3: Materials					
3.1	Investigating classroom resources	Planning investigations	SC5-WS-03	Reducing risks in investigations	
3.3	Making and mining 'ore'	Planning investigations	SC5-WS-03	Identifying variables	
3.8	Properties of pure versus alloy metals	Planning investigations	SC5-WS-03	Identifying variables	✓
3.10	Student-designed investigation: properties of common substances	Planning investigations	SC5-WS-03	Planning an investigation that is reliable and valid	
3.13	Modelling organic compounds	Communicating	SC5-WS-08	Constructing presentations on findings	
3.15A	Complete and incomplete combustion reactions	Planning investigations	SC5-WS-03	Developing an aim	
3.15B	Combustion of fuels	Planning investigations	SC5-WS-03	Identifying variables	
3.16	Polymers in the environment	Planning investigations	SC5-WS-03	Reducing risks in investigations	
3.17A	Biodegradability of packaging	Problem-solving	SC5-WS-07	Proposing solutions to scientific problems	
3.17B	Properties of 'Ghostbuster' slime	Problem-solving	SC5-WS-07	Explaining scientific problems	
3.19	Comparing drinking straws	Problem-solving	SC5-WS-07	Explaining scientific problems	
Focus Area 4: Environmental sustainability					
4.1	The sustainability game	Problem-solving	SC5-WS-07	Evaluating solutions to a problem	
4.3	Observing the weather	Analysing data and information	SC5-WS-06	Representing data to identify patterns and trends	
4.4	The greenhouse effect	Analysing data and information	SC5-WS-06	Assessing results for reliability and validity	
4.7A	Modelling thermal expansion	Analysing data and information	SC5-WS-06	Representing data to identify patterns and trends	
4.7B	Melting ice and sea-level rise	Analysing data and information	SC5-WS-06	Evaluating statements based on data	
4.8	Modelling ocean acidification	Analysing data and information	SC5-WS-06	Assessing data for reliability and validity	
4.12	Making bioplastic	Problem-solving	SC5-WS-07	Evaluating claims based on evidence	

Investigation number	Investigation title	Working scientifically process	Syllabus outcome	Working scientifically content focus	Teacher demon-stration
Focus Area 5: Genetics and evolutionary change					
5.1	Extracting DNA from strawberries	Communicating	SC5-WS-08	Presenting scientific findings	
5.3	DNA lolly model	Communicating	SC5-WS-08	Selecting ways to present information	
5.6	Genetic trait survey	Communicating	SC5-WS-08	Organising information using digital technologies	
5.12	Natural selection in practice	Processing data and information	SC5-WS-05	Constructing appropriate graphs	
5.13A	Dating fossils	Processing data and information	SC5-WS-05	Organising data with tables and graphs	
5.13B	Comparative anatomy	Processing data and information	SC5-WS-05	Using data to support hypotheses	
Focus Area 6: Reactions					
6.1	Investigating the law of conservation of mass	Observing	SC5-WS-01	Using scientific tools to make observations	
6.3	Simulating chemical reactions	Observing	SC5-WS-01	Using scientific tools	
6.4A	Synthesis of iron oxide	Planning investigations	SC5-WS-03	Reducing risks in investigations	
6.4B	Decomposition of copper(II) carbonate	Planning investigations	SC5-WS-03	Developing an aim	
6.5A	Growing metallic crystals: metal displacement reactions	Questioning and predicting	SC5-WS-02	Making predictions based on scientific knowledge	
6.5B	Precipitation reactions	Questioning and predicting	SC5-WS-02	Making predictions based on scientific knowledge	
6.6A	Cleaning coins	Conducting investigations	SC5-WS-04	Implementing safe practices	
6.6B	Acid or base? The pH of common household substances	Conducting investigations	SC5-WS-04	Collecting and recording data	
6.7A	Neutralising hydrochloric acid	Conducting investigations	SC5-WS-04	Accurately collecting and recording data, information, evidence and findings	
6.7B	The effects of indicators on acids and bases	Conducting investigations	SC5-WS-04	Using scientific equipment to conduct investigations and to gather first-hand data and information	
6.7C	Reactions of acids with metals	Conducting investigations	SC5-WS-04	Collecting and recording data	
6.7D	Reactions of acids with carbonates	Conducting investigations	SC5-WS-04	Accurately collecting and recording data, information, evidence and findings	
6.8A	The effect of concentration on the rate of reaction	Questioning and predicting	SC5-WS-02	Constructing a scientific question	

Investigation number	Investigation title	Working scientifically process	Syllabus outcome	Working scientifically content focus	Teacher demon-stration
6.8B	The effect of temperature on the rate of reaction	Questioning and predicting	SC5-WS-02	Making predictions based on scientific knowledge	
6.9A	The effect of surface area on the rate of reaction	Planning investigations	SC5-WS-03	Identifying variables	
6.9B	The effect of a catalyst on the rate of reaction	Planning investigations	SC5-WS-03	Developing an aim	
6.9C	Student-designed investigation: investigating rate of reactions	Planning investigations	SC5-WS-03	Planning an investigation that is reliable and valid	
6.10	Modelling the expanding universe	Observing	SC5-WS-01	Using observations and measurements to answer questions	
6.12	Half-life coin experiment	Observing	SC5-WS-01	Using observations and measurements to answer questions	
6.15	Nuclear energy debate	Questioning and predicting	SC5-WS-02	Selecting questions to investigate scientific problems	
Focus Area 7: Waves and motion					
7.1	Making a wave machine	Conducting investigations	SC5-WS-04	Collecting and recording data, information, evidence and findings accurately	
7.2	Waves in a slinky and calculating frequency	Conducting investigations	SC5-WS-04	Conducting first-hand investigations and accurately recording the collected data and identifying errors	
7.4	Investigating amplitude, frequency and pitch of sound waves	Conducting investigations	SC5-WS-04	Using scientific equipment to conduct investigations and to gather first-hand data and information	✓
7.5	The Doppler effect	Conducting investigations	SC5-WS-04	Collecting and recording information, evidence and findings accurately	
7.9A	The law of reflection	Conducting investigations	SC5-WS-04	Using scientific equipment to conduct investigations and to gather first-hand data and information	
7.9B	Refraction	Conducting investigations	SC5-WS-04	Collecting and recording data, information, evidence and findings from investigations accurately	
7.10	Eye dissection	Processing data and information	SC5-WS-05	Extracting data from a first-hand source	
7.12	Cars and pedestrians	Conducting investigations	SC5-WS-04	Conducting first-hand investigations and accurately recording the collected data and identifying errors	
7.13	Ticker timers	Processing data and information	SC5-WS-05	Calculating a range of measurements using data and formulas, and using SI units	
7.14A	Car crashes and inertia	Conducting investigations	SC5-WS-04	Collecting and recording data and evidence from first-hand investigations accurately	
7.14B	Balloon rockets	Conducting investigations	SC5-WS-04	Using scientific equipment to gather data	
7.15	Acceleration and mass	Conducting investigations	SC5-WS-04	Conducting first-hand investigations and accurately recording the collected data and identifying errors	

Investigation number	Investigation title	Working scientifically process	Syllabus outcome	Working scientifically content focus	Teacher demon-stration
Focus Area 8: Data Science 2					
8.2	What if Earth stopped rotating for 1 second?	Problem-solving	SC5-WS-07	Explaining problems using cause-and-effect relationships	
8.3	Do red cars go faster?	Problem-solving	SC5-WS-07	Evaluating scientific claims	
8.4	Sugary drinks and teeth	Problem-solving	SC5-WS-07	Proposing solutions to problems	
8.5	Where did Earth's water come from?	Communicating	SC5-WS-08	Presenting scientific findings	
8.6	The influence of advertising	Analysing data and information	SC5-WS-06	Assessing information for accuracy, reliability and validity	
8.7	Earth is flat!	Analysing data and information	SC5-WS-06	Evaluating conclusions based on data	
8.8	How big is big data?	Analysing data and information	SC5-WS-06	Describing trends from collected data	
8.9	How to use big data	Analysing data and information	SC5-WS-06	Explaining relationships between data and information	
8.10	State of Origin	Analysing data and information	SC5-WS-06	Evaluating conclusions based on data	
8.11	Heads and tails	Analysing data and information	SC5-WS-06	Explaining relationships between datasets and information	
8.12	What is your temperament?	Problem-solving	SC5-WS-07	Evaluating claims based on evidence	

Notes:

Conducting investigations: Extract information from a wide range of reliable secondary sources and acknowledge these sources using an accepted referencing style. Covered in spreads 1.7, 7.1, 7.4, 7.12.

Communicating: Recognise that scientific texts develop arguments by encouraging the reader to adopt a specific perspective and positioning them to accept the authority of a text. Covered in spreads 2.1, 2.14, 3.4, 3.18, 5.15.

Investigation 1.1

30 min

Galileo's pendulum

Process: Observing

Focus: Using observations and measurements to answer questions

It is important to make and record accurate observations and measurements, so that your results are meaningful. Accurate measurements allow you to make clear inferences about your observations and to answer questions clearly based on these observations and evidence you have collected.

Hint: *Think about conservation of energy and energy transformation and apply it to your pendulum.*

Aim

To investigate the law of conservation of energy using a pendulum

Materials

- mass carrier (50 g)
- 50 g mass
- fishing line or poly string
- rubber stopper with hole
- retort stand
- bosshead and clamp
- metre ruler
- pencil or pen

Method

1 Copy the results table into your notebook, adding a title and rows as needed.

2 Tie the mass carrier and mass to the end of the fishing line, forming a pendulum.

3 Pass the other end of the fishing line through the rubber stopper and tie it off.

4 Use the metre ruler to measure the starting height above the ground.

5 Insert the rubber stopper into a clamp on a retort stand as shown in Figure I1.1.

6 Keeping the string taut, raise the mass up until the string is at about a 45 ° angle to the ground.

7 Use the metre ruler to measure how far above the ground this is.

8 Release the mass, allowing it to swing backwards and forwards. Use the metre ruler to measure the height the mass returns to on its first swing. Record this height in your results table. Then undertake further trials.

9 Interrupt the swing of the pendulum by placing a pencil in the path of the string. What height does the pendulum return to now?

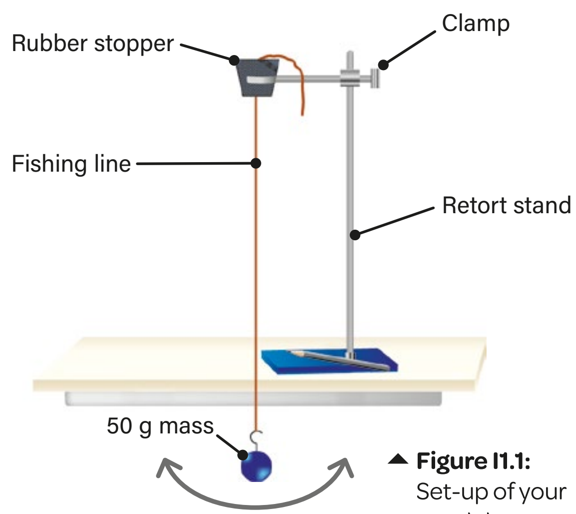


Figure I1.1: Set-up of your pendulum

Table I1.1: Results

Starting height (cm)	Trial 1 (cm)	Trial 2 (cm)	Trial 3 (cm)	Average (cm)

Questions

1 Compare the return height to the starting height without the pencil in place. What did you observe?

2 How does this investigation demonstrate the conservation of energy?

3 Explain any energy losses in this investigation.

4 Propose a reason why the return height changed when the pencil was placed in the path.

5 How could this experiment be improved?

Conclusion

Copy and complete:

'The results show that: *(respond to the aim).*'

Investigation 1.2

30 min

Energy efficiency of bouncing balls

Process: Problem-solving

Focus: Explaining scientific problems and phenomena using cause-and-effect relationships

During investigations, scientists try to explain phenomena using cause-and-effect relationships. In this investigation, you will test the relationship between the type of material a ball is made of and the energy efficiency of the ball when it bounces. As you measure the bounce height of the balls, think about how you will explain energy efficiency. Which ball is most efficient?

Hint: *When you take your measurements, think about the differences between each ball, including the types of energy transformations you can see and hear.*

Aim

To investigate the energy efficiency of different types of balls

Materials

- metre ruler
- retort stand
- boss head and clamp
- several types of balls, e.g. tennis ball, golf ball, squash ball, handball, hi-bounce ball

Method

1. Formulate your hypothesis. You may use the following sentence stem.
   It can be hypothesised that if *(something to do with your independent variable)*, then *(something to do with your dependent variable)*.
2. Copy the results table into your notebook, adding a title and rows as needed.
3. Clamp the metre ruler to the retort stand, so that the zero mark is at the bottom.
4. Hold the first ball just above the 1-metre mark of the ruler.
5. Drop the ball and measure the maximum height the bottom of the ball reaches as it bounces back up. Record your results in your results table.
6. Repeat steps 4 and 5 for two more trials of the same ball.
7. Repeat steps 4–6 for each type of ball.
8. Calculate the energy efficiency (%) of each type of ball by dividing the average rebound height by the drop height. Record this in your results table.

Questions

1. Compare the results, and identify which balls were the most and the least energy efficient.
2. Identify the ball that lost the most energy. Explain how you know this.
3. Outline any connection between the loudness of the bounce and the energy efficiency of the ball.
4. Identify two possible sources of energy loss for a bouncing ball.
5. Select any two balls from your results. Consider each ball's features and propose a reason why one ball may be more energy efficient than the other.
6. Describe any issues you had in measuring the bounce height of the ball and how you made sure your data was as accurate as possible.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim and your hypothesis).*'

Table I1.2: Results

Type of ball	Starting drop height (cm)	Rebound height (cm)				Energy efficiency (%)
		Trial 1 (cm)	Trial 2 (cm)	Trial 3 (cm)	Average (cm)	
Handball	100					
Tennis ball	100					

Investigation 1.6A

15 min

Modelling a simple circuit

Process: Observing

Focus: Making inferences from observations

Scientists use models to simplify and explain ideas. Models make things easier to understand and visualise. In this investigation, you will observe a model for a circuit to help understand current, voltage and resistance.

Hint: *Observe and compare the components of the model to the components in a circuit.*

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.

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)*.'

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.

Investigation **1.6B**

30 min

Conductors and insulators

Process: Observing

Focus: Recording observations and measurements accurately

In this investigation, you will test a variety of common materials to see if they are conductors or insulators. A simple circuit will be used to test the materials. The circuit includes a light and an ammeter, which can help you to measure and assess the properties of each material and infer whether it is a conductor or an insulator.

Hint: *Think about conductors and insulators, and which will allow current to flow. Consider whether you expect a high or low reading on the ammeter in each case.*

Aim

To investigate which materials are electrical conductors, and which are insulators, in an electrical circuit

Materials

- selection of materials (e.g. fabric, different plastics, iron nail, strip of tin, icy pole stick, strip of copper, strip of aluminium, chalk, graphite from a pencil, glass)
- 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

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.

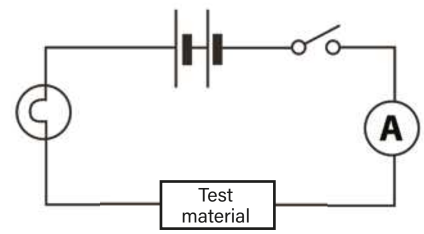


Figure I1.6B: Testing circuit with a light and an ammeter

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.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table I1.6B: Results

Substance tested	Did light turn on? (Y/N)	Ammeter reading (mA)	Conductor or insulator?

Investigation 1.7

30 min

Exploring Ohm's law

Process: Conducting investigations

Focus: Conducting first-hand investigations and accurately recording data

In this investigation, you will set up a simple circuit to measure and record the voltage and current. Using the results, you will demonstrate Ohm's law in action, including the relationship between voltage, current and resistance.

Hint 1: Ensure that the ammeter and voltmeter are connected correctly, considering the direction of current flow.

Hint 2: You will use a variable power supply instead of a battery. Ensure you adjust the output voltage accurately.

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
- 0–5A 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.

Table I1.7: Results

Power supply voltage (V)	Potential difference (voltmeter reading) (V)	Current (*I*) (ammeter reading) (A)
2		
4		
6		
8		
10		
12		

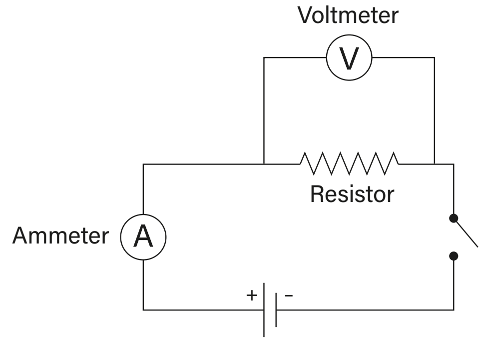


Figure I1.7: Circuit diagram for measuring voltage and current

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.

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 Explain what the slope of the line in the graph represents.

3 Add another column to your results table and calculate the resistance, using your results.

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)*.'

Investigation 1.8

Series and parallel circuits

Process: Conducting investigations

Focus: Using scientific equipment to conduct investigations

In this investigation, you will set up simple series and parallel circuits to measure and compare the voltage and current. Voltage and current behave differently in each type of circuit.

Hint: *Make sure you set up the voltmeter to measure in parallel with the resistors, and the ammeter in series, and collect the data accurately.*

Aim

To measure and compare the voltage and current in series and parallel circuits

Materials

- 2 ammeters
- voltmeter
- 9 electrical leads
- 2 × 10 Ω resistors
- power pack

Method

1 Copy the results table opposite into your notebook, adding a title.

Part A: Series circuit

2 Set up the circuit as shown in Figure I1.8a.

3 Set the power pack to 2 V and turn it on. Record the voltage and current across each resistor in the results table.

4 Repeat step 3, increasing the power supply by 2 V each time, until your results table is complete.

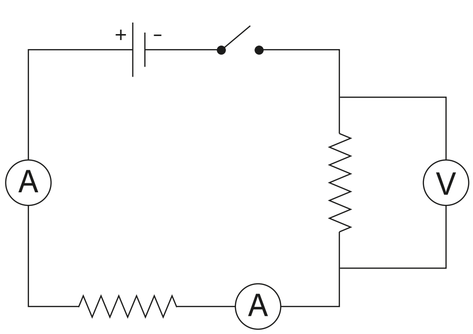


Figure I1.8a: Series circuit for Part A

Part B: Parallel circuit

5 Set up the circuit as shown in Figure I1.8b.

6 Set the power pack to 2 V and turn it on. Record the voltage and current across each resistor in the results table.

7 Repeat step 6, increasing the power supply by 2 V each time, until your results table is complete.

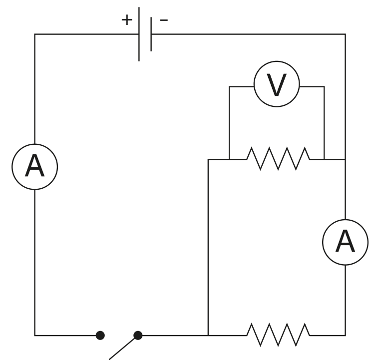


Figure I1.8b: Parallel circuit for Part B

Questions

1 Describe the relationship between the voltage of the power pack and the voltage across both resistors in a:

a series circuit.

b parallel circuit.

2 Compare the current through the ammeter in the series circuit and the parallel circuit.

3 a If these circuits were running off a battery, make an inference about which circuit (series or parallel) would run the battery down the fastest.

b Justify your answer to part **a** using your observed results.

4 Describe how you made sure the ammeter and voltmeter were correctly added to the circuits.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

45 min

Table I1.8: Results

Power supply (V)	Part A: Series			Part B: Parallel		
	Potential difference resistor 1 (V)	Potential difference resistor 2 (V)	Current (A)	Potential difference resistor 1 (V)	Potential difference resistor 2 (V)	Current (A)
2						
4						
6						
8						
10						
12						

Investigation 1.9

Comparing energy in appliances

Process: Problem-solving

Focus: Using given criteria to find solutions to scientific problems

In this investigation, you will collect data about electrical appliance efficiency from a secondary source and collate it in a table. You will then use criteria to compare appliances and solve problems.

Hint: *When selecting appliances to compare, make sure they have similar features. For example, computer monitors should be of a similar size and screen type.*

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, a clothes washer will allow you to select the capacity (how large it is).
5. Copy the results table opposite 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 1 year.
3. Calculate the difference in cost between your most and least efficient appliance, over:
   a. 1 year.
   b. 1 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 1 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)*.'

30 min

Table I1.9: 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				

Investigation 1.10

Insulation and heat transfer

Process: Problem-solving

Focus: Suggesting solutions to familiar scientific problems

In this investigation, you will test the effectiveness of different insulating materials. After assessing your results, you will apply your knowledge to some everyday problems to think about how insulators can be used.

Hint 1: *Test a range of insulators to compare their properties and effectiveness.*

Hint 2: *Ensure each beaker is covered with insulation in a consistent way with as few gaps as possible.*

Aim

To investigate insulating materials and the transfer of heat to see if some materials are better insulators than others

Materials

For entire class:

- safety glasses
- selection of insulating materials (e.g. cardboard, wool, aluminium foil)

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.

- 4 × 250 mL conical flasks (one for each material)
- 4 thermometers
- 4 rubber stoppers with hole
- kettle (or hot water from tap)
- scissors
- tape

Method

1. Copy the results table opposite into your notebook, adding a title and rows to record temperature for up to 30 minutes.
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.

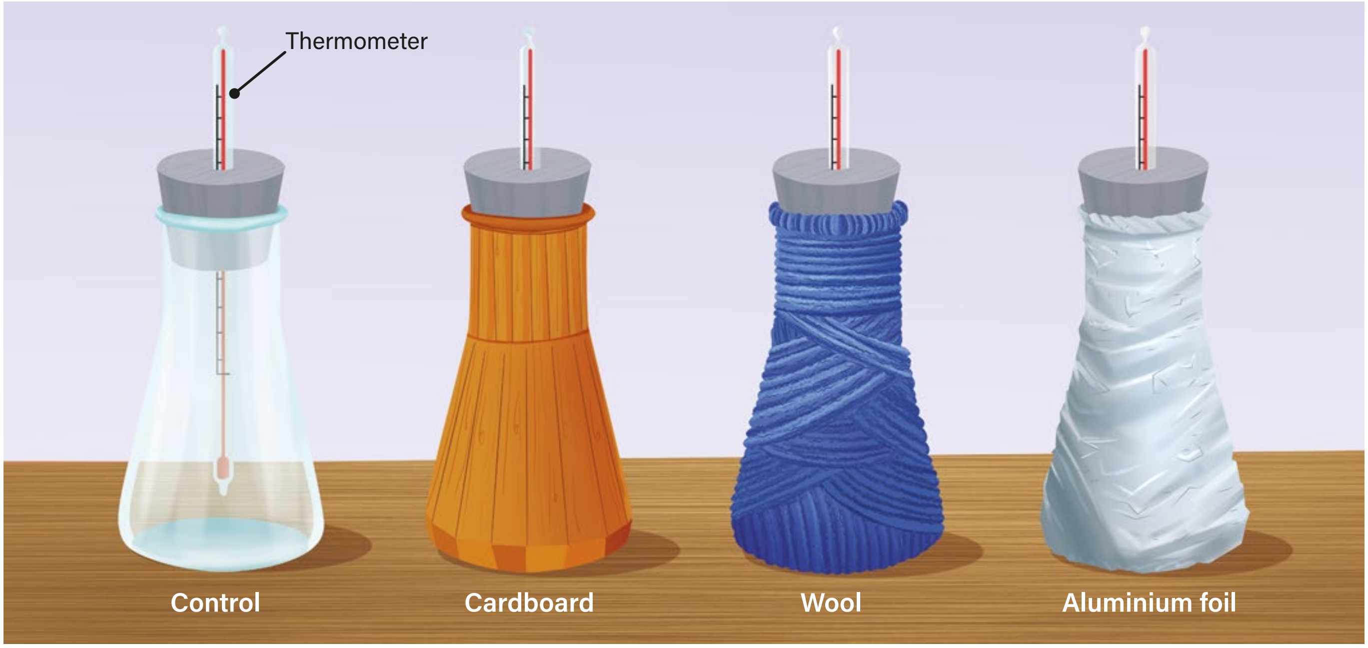


Figure I1.10: Set up your beakers, with one as a control and the others with insulation.

45 min

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 Construct a line graph of temperature (y-axis) against time (x-axis) showing each insulator.
2 Identify the material that was the best insulator. Justify your answer with evidence.
3 Identify the material that was the worse insulator. Justify your answer with evidence.
4 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.
5 Propose reasons why a shiny silver 'space blanket' is used by emergency workers to cover people at the scene of an accident.
6 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 I1.10: Results

Time (minutes)	Water temperature (°C)			
	Control	Material A	Material B	Material C
0				
5				
10				
15				

Investigation **1.11**

Atmospheric convection and inversion layer

TEACHER DEMONSTRATION

Process: Problem-solving

Focus: Explaining scientific problems and phenomena using cause-and-effect relationships

In this investigation, you will view a demonstration of what happens in the atmosphere on a normal day when hot air is able to rise into the atmosphere, and when hot air is trapped at ground level by a temperature inversion. You will use your knowledge to explain the relationship between smog and a temperature inversion, outlining how that may affect people in a city.

Hint: *Think about the hot water and cold water in Parts A and B of the demonstration, and how they represent layers in the atmosphere on different days.*

Aim

To model how thermal pollution affects circulation in the atmosphere

Materials

- 4 identical small, wide-mouthed jars without spouts (e.g. gas jars)
- kettle (or hot water from a tap)
- red food colouring
- stirring rod
- large, shallow tray
- very cold (but not iced) water
- blue food colouring
- cardboard or waxed paper

Method

Part A: Investigating convection

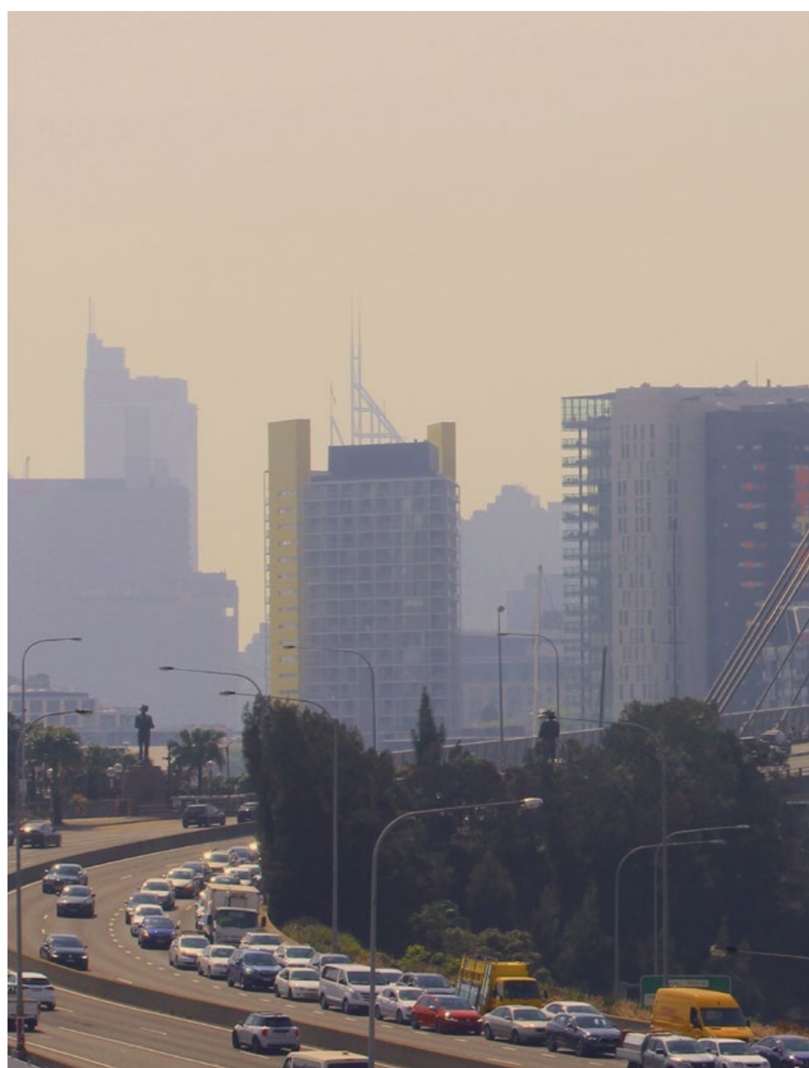
1 Your teacher will half-fill one of the jars with hot water. They will add 1 drop of red food colouring. Observe how it mixes. Your teacher will mix the food colouring in completely if needed.

2 Your teacher will place the jar in the shallow tray. They will then slowly add hot water until there is a slight bulge of water over the top of the rim of the jar.

3 Your teacher will carefully half-fill the other jar with cold water and add 1 drop of blue food colouring. Observe how it mixes. Your teacher will mix the food colouring in completely if needed.

4 Observe as your teacher fills this jar with cold water all the way to the top and places the card or waxed paper over it. They will tap the card gently so that the card forms a seal with the rim of the jar.

5 Your teacher will take the jar with cold water in one hand, with their other hand on the card. They will quickly, and without hesitating, pick it up and flip the jar upside down.



45 min

6 Your teacher will place the card and the jar of cold water on the jar of hot water so that the rims line up exactly.

7 Your teacher will carefully remove the card without disturbing the jars.

Part B: Investigating inversion

Watch as your teacher repeats the steps in Part A, but this time with the jar with the blue-coloured cold water in the tray and the card on top of the jar with the red-coloured hot water. They will turn the red jar upside down and put it on top of the jar with blue-coloured cold water.

Questions

1 a Record your observations for Part A.

b Record your observations for Part B.

2 Identify which part of the investigation represented the atmosphere:

a with a thermal pollution layer.

b on a normal day.

3 Using your observations, explain what happens to the circulation of air and heat at Earth's surface on a normal day.

4 Using your observations, explain what happens to circulation of air and heat at Earth's surface when there is smog causing a temperature inversion.

5 Explain the relationship between smog and a temperature inversion, outlining how that may affect people in a city.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation 2.1A

Sensory receptors

Process: Communicating

Focus: Using digital technologies to present data

When an investigation has been conducted multiple times, scientists can collate the data they have collected and represent it in a summary table. This improves the reliability of their results.

Hint: *What data could you collate from this investigation to ensure that your results were consistent with those of other students in your class?*

Aim

To determine which of three areas of the body has the highest concentration of pressure receptors

Materials

- 30 cm ruler or vernier calipers
- 3 lengths of copper wire , or 3 paperclips or vernier calipers

Method

You will be testing three different areas of the body to determine if the subject can tell the difference between being poked with one wire tip, a bent wire with the tips close together (5 mm apart), and a bent wire with the tips further apart (15 mm).

1. Copy the results table into your notebook, adding a title.
2. Bend one of the wires so that the tips are 5 mm apart. Bend another length of wire so the tips are 15 mm apart. Keep the third length of wire unbent.
3. The test subject closes their eyes and holds out their dominant hand palm up and with the fingers together.
4. The tester *gently* pokes the subject's forefinger with the sets of wires. Poke the subject 10 times with each set of wires (a total of 30 times), but mix up which wires you are using. Do it randomly, so the subject cannot guess which wire you are using.
5. Each time they are poked, the subject must say which set of wires they think was used. The tester records the results in the table, using a tick for a correct statement and a cross for an incorrect statement. Do not tell the subject whether they are right or wrong.
6. Repeat steps 4 and 5 for the forearm and the back of the neck.

Questions

1. Which part of the body had the highest concentration of receptors (i.e. the subject had the most correct answers)? Why do you think this is?
2. Which part of the body was the least sensitive (i.e. the subject got the most incorrect answers)? Why do you think this is?
3. Calculate the percentage of times the correct result was selected for each of the three parts of the body.
4. Compare your results with those of the rest of the class. Were they consistent?
5. Use the percentages from each group in your class to construct a digital pie chart showing the comparative average percentages for each body part.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Figure I2.1A: Copper wire typically comes in coils like this, and should be easy to cut and bend. Make sure the edges of your pieces of wire are not sharp!

PLACING OBJECTS ONTO ANOTHER PERSON'S SKIN CAN CAUSE DAMAGE. MAKE SURE YOU PLACE THE WIRE(S) LIGHTLY EACH TIME. DO NOT USE FORCE TO POKE THEM INTO YOUR LAB PARTNER'S BODY.

30 min

Table I2.1A: Results

Trial	Finger			Forearm			Back of neck		
	1 point	2 points 5 mm apart	2 points 15 mm apart	1 point	2 points 5 mm apart	2 points 15 mm apart	1 point	2 points 5 mm apart	2 points 15 mm apart
1									
2									
...									
10									
Total correct									

Investigation 2.1B

Reaction time

Process: Communicating

Focus: Presenting scientific findings

Once an investigation is complete, it is important to collate and present your findings in an appropriate way, so that your results can be interpreted by other scientists. This ensures that the data you have collected can be compared to see if the same results are consistently obtained from a specific investigation.

Hint: *What type of graph would clearly display your results from this investigation?*

(More information about graph types is available in the Science how-to section on pages 457–61.)

Aim

To determine whether a person's dominant or non-dominant hand has a faster reaction time

Materials

- 30 cm ruler

Method

1. Copy the results table into your workbook, adding a title and rows as needed.
2. Have a partner sit at a table. Ask them to nominate their dominant hand (usually the hand they write with) and have them rest that arm on the table and put their hand out over the edge (see Figure I2.1B). Get them to hold their thumb and forefinger about 2 cm apart, so that they can catch a dropped ruler in a pincer grip.
3. Hold the ruler upside down between their open thumb and forefinger but just above it, so that the 0 cm mark on the ruler is aligned with the top of their thumb.
4. Without any obvious warning, drop the ruler for your partner to catch. Record the distance that they caught it at in the results table.
5. Repeat step 4 nine times for the dominant hand. Then repeat the trial 10 times for their non-dominant hand.
6. Calculate the average distance (in centimetres) at which the ruler was caught.
7. Use this value to calculate the person's average reaction time using the formula:

$$t = \sqrt{\frac{d}{50g}}$$

where t = time to react (s)

d = distance ruler dropped (cm)

g = acceleration due to gravity (9.8 m s^{-2}).

Record this time in the results table.

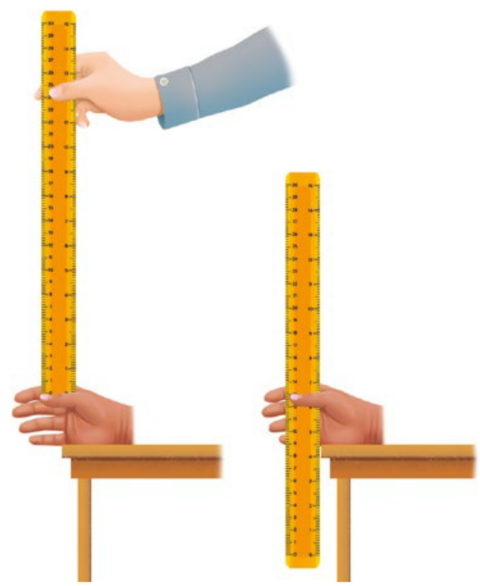


Figure I2.1B: Make sure the ruler is dropped from directly in line with the thumb of the person catching it.

Questions

1. Which hand had the faster reaction time? Was this what you expected? Explain why or why not.
2. Compare your results with the results from the other groups in your class.
3. Construct a graph that shows the reaction times of each student in your class for their dominant hand.

15 min

4 Construct a graph that shows the difference in distances at which your or your partner caught the ruler with their non-dominant hand.
5 Explain how these representations allow your results to be compared to the results of other investigations into reaction time.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table I2.1B: Results

Trial	Distance dropped before ruler caught (cm)	
	Dominant hand	Non-dominant hand
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
Average reaction distance (cm)		
Average reaction time (s)		

Investigation 2.3

Sheep brain dissection

Process: Communicating

Focus: Constructing presentations on findings

When scientists conduct first-hand and second-hand investigations, they need to be able to communicate the information that they learn to particular audiences. Good presentations often include both first- and second-hand data to support the information they are providing.

Hint 1: *Where could you find additional information about the structure and function of the brain?*

Hint 2: *How will you show your audience that the information you are providing is in your own words? (More information about referencing is available in the Science how-to section on page 443.)*

Aim

To investigate the structure of a mammalian brain

Materials

- safety glasses
- nitrile gloves
- disposable apron or laboratory coat (for protection against biological material 'splashes')
- newspaper
- dissecting board
- sheep brain
- scalpel
- paper towel
- disinfectant
- heavy-duty garbage bags for disposal of biological waste

Method

1. Place some newspaper on the bench and the dissecting board on top of it.
2. Carefully place the sheep brain on the dissecting board. Identify the cerebrum, cerebellum and brain stem.
3. Draw a diagram of the brain, labelling these structures. (Alternatively, take a photograph.)
4. Notice that the cerebrum is made up of two halves, called hemispheres. Use the scalpel to carefully cut the brain in half, so that these hemispheres are separated.
5. Use the photograph in Figure I2.3 to help you identify the major structures of the brain. Draw a diagram of this cross-section of the brain, labelling as many structures as you can identify.
6. Cut across one of the hemispheres, perpendicular to the corpus callosum.
7. Notice that some parts of the cerebrum are white, whereas others are more pinky-grey. The white area is known as 'white matter', and the pinky-grey area is the 'grey matter'.
8. Draw a diagram of this cross-section, labelling the grey matter and the white matter.
9. When you have completed your dissection, carefully clean up and disinfect your work area.

Questions

Research to help you answer the following questions.

1. Find images that will allow you to compare the size and shape of a sheep brain and a human brain. What do you think influences these differences?
2. Find out more about the functions of the following brain structures.
   - Cerebrum
   - Cerebellum
   - Brain stem (spinal cord, medulla oblongata, pons)
   - Corpus callosum
   - Hypothalamus
   - Thalamus
3. What is the difference between 'white matter' and 'grey matter'?

⚠

WEAR EYE AND HAND PROTECTION.

TAKE CAUTION WITH CUTTING IMPLEMENTS.

DISPOSE OF ALL MATERIALS AS DIRECTED BY YOUR TEACHER. WASH YOUR HANDS AFTERWARDS.

45 min

4 Use your findings and secondary-sourced information to create a poster comparing a human brain and a sheep brain, in terms of their size, structure and function.

5 Construct a reference list to acknowledge any secondary sources you used to help you answer questions 2 and 4.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

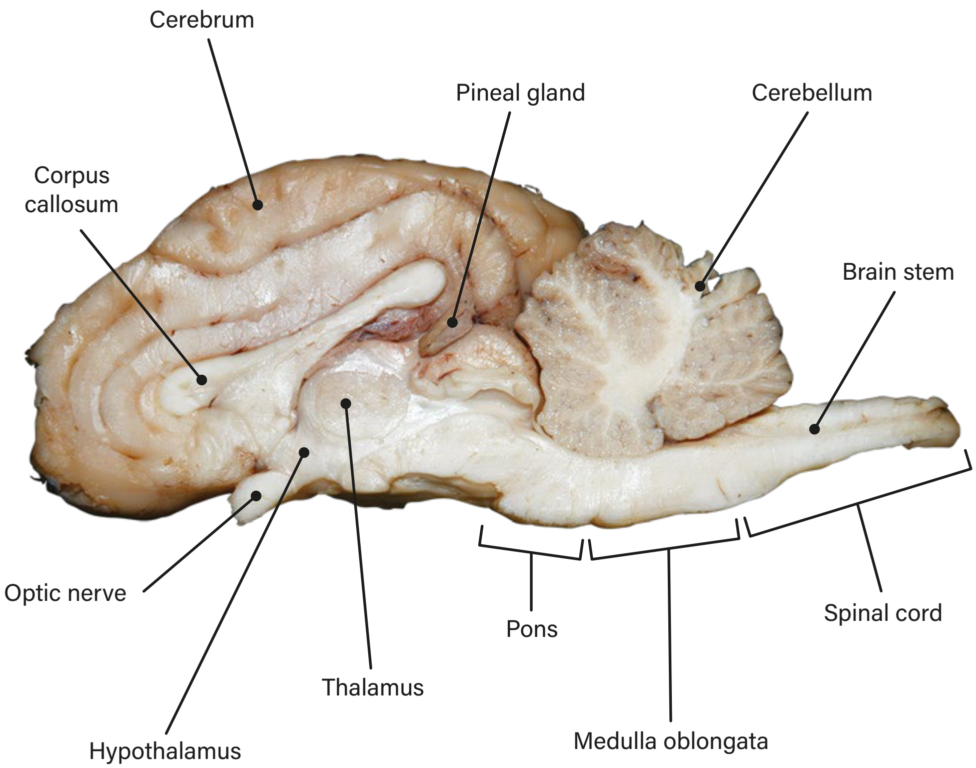


Figure I2.3: Use this photograph to identify the different parts of your sheep brain.

Investigation 2.5

45 min

Cardiovascular disease in Australia

Process: Analysing data and information

Focus: Assessing second-hand data for accuracy, reliability and validity

When collecting data, it is important to ensure that what you are collecting is accurate, reliable and valid. For second-hand data, sources must meet a number of conditions in order for the data to safely meet all three of these criteria.

Hint: Consider the sources you are looking at. Do they meet the components of the CRAAP test? (More information about scientific writing is available in the Science how-to section on pages 433–45.)

Aim

To investigate data on cardiovascular disease in Australia

Materials

- computer with internet access

Method

1 Go to the Australian Bureau of Statistics website and navigate to the following health conditions by clicking on 'Statistics', then 'Health' and then:

  a 'Health conditions and risks' and 'Heart, stroke and vascular disease'.

  b 'Causes of death' then 'Causes of death, Australia' and then scroll down to 'Australia's leading causes of death'.

2 From the webpage in Question 1a, find and compile information on ischaemic heart disease, including the total number of deaths, number of deaths by sex (male and female), and number of deaths by state.

3 Record your data in a table like Table I2.5a.

4 From the webpage in Question 1b, look at the graph that shows the proportion of individuals with heart, stroke and vascular disease by age, and record this as a table like Table I2.5b.

Questions

1 What does the data tell you about the deaths from heart disease in Australia?

2 Construct a pie chart that compares the number of deaths by heart disease across the states and territories in Australia. See the Science How-to section on pages 459–61 for help with constructing your pie chart.

3 Is your pie chart an accurate way to compare data on heart disease across Australia? Why or why not?

4 Assess the websites you have used to gather your data for their accuracy, reliability and validity.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Table I2.5a: Ischaemic heart disease deaths by category

Category	Number of deaths in 2022
Total	
Male	
Female	
New South Wales	
Victoria	
Queensland	
South Australia	
Western Australia	
Tasmania	
Northern Territory	
Australian Capital Territory	

Table I2.5b: Proportion of people with heart, stroke and vascular disease by age

Age range (years)	Proportion of people with heart, stroke and vascular disease (%)

30 min

Modelling direct disease transmission

Process: Communicating

Focus: Using digital technologies to present information

When collecting and presenting information from an investigation, it is often appropriate to collate any findings in a digital format. Digital graphs, tables and models are useful methods of collating data when preparing to present it to an audience.

Hint 1: *What specific programs could be used to create tabular and graphical data from investigations?*

Hint 2: *How could you create a digital model that shows the results of an investigation?*

Aim

To model the direct transmission of an infectious disease

Materials

- safety glasses
- nitrile gloves
- class set of small beakers or test tubes (1 per student)
- tap water
- 0.5 M sodium hydroxide
- 1 bottle phenolphthalein indicator

SODIUM HYDROXIDE CAN BE HAZARDOUS TO SKIN AND EYES. WEAR SAFETY GLASSES AND NITRILE GLOVES, AND DO NOT PUT ANY OF THE SOLUTION FROM THE BEAKER ONTO YOUR SKIN.

Method

1. Copy the results table into your notebook, adding a title.
2. Your teacher will have a set of beakers up the front that are all a third full of water.
3. Your teacher will add a small amount of sodium hydroxide to one of the beakers without the class looking. This is the ‘infected’ beaker.
4. Everyone collects one beaker and stands around the room.
5. When everyone has a beaker, randomly move about the room and ‘shake hands’ with three other students from your class, by pouring all the solution from both beakers into one beaker, and then pouring half back into the empty beaker.
6. Once you have completed three ‘handshakes’, return to your desk and place your beaker at the front of it.
7. Your teacher will then come around and place some phenolphthalein indicator into each beaker, to see who has been infected.
8. Repeat the activity with four and then five ‘handshakes’, rather than three.

Figure I2.6Aa: Clear liquid at the conclusion of the investigation means you remained ‘uninfected’. Pink liquid means you have been infected.

continues

Figure I2.6Ab: How to 'shake hands'

Questions

1 How many students remained uninfected at the conclusion of the activity?

2 Construct a digital pie chart that shows infected versus uninfected students for each number of handshakes.

3 How does the number of infected students change as the number of handshakes increases?

4 What does this information tell us about the transmission of diseases that are spread by direct contact?

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table I2.6A: Results

Number of handshakes	Number of infected students	Number of uninfected students
3		
4		
5		

Investigation 2.6B

45 min

Modelling indirect disease transmission

Process: Communicating

Focus: Presenting scientific findings

Once data has been collected, it needs to be interpreted and presented, in order to compare it to other findings. Using specific methods of presentation allows particular audiences to be targeted, so that you can ensure your information is understood.

Hint 1: Who are you trying to communicate your information to?

Hint 2: What format would be most appropriate for presenting your information?

Figure I2.6B: Walk along your row of desks and select only one object to touch.

Aim

To model the indirect transmission of infectious diseases

Materials

- detergent or bubble mixture
- 4 beakers
- 4 small plastic tubs
- 4 markers
- tap water

Method

1. Copy the results table into your notebook, adding a title.
2. Arrange the room so there are four rows of desks, with space to line up on either side of them.
3. Place one beaker that is half-full of water, one plastic tub and one marker on each row of desks.
4. As a class, line up on either side of each row of desks.
5. One at a time, walk along the row of desks and touch one item. This item represents a mode of indirect disease transmission – waterborne, airborne, vector or surface. Record this item.
6. While you are walking, your teacher will be blowing bubbles throughout the desk area.
7. Return all items and go back to your desk. Your teacher will tell you which mode of indirect transmission was responsible for the 'disease' in each row. If you selected the item that represents this mode of transmission, you were infected!

Questions

1. Which item was the infected item on the desks?
2. What form of indirect transmission do you think this object might represent, and why?
3. How many students in the class were infected with the disease?
4. How does this investigation show the indirect transmission of diseases?
5. Construct a presentation to show your findings to a Year 8 student. Link your findings from this investigation to disease transmission.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table I2.6B: Results

Item touched	Infected item	Bubbles encountered	Infected/uninfected

Investigation 2.9

The contagion game

Process: Analysing data and information

Focus: Drawing conclusions based on patterns in data

Once data has been collected and recorded from an investigation, it can be used to make inferences, interpretations and conclusions that interpret and draw conclusions about what it means. Drawing conclusions from data allows us to apply it to real-world concepts, such as vaccination.

Hint 1: What patterns can you see in the data you have collected from this investigation? Are there any trends?

Hint 2: What do these trends show you about the effectiveness of vaccinations?

Aim

To investigate how vaccination levels affect the spread of infectious diseases

Materials

- small scraps of paper in two colours for each student
- boxes to store paper
- notecards or index cards
- pencils or pens

Method

1. Copy the results table into your notebook, adding a title.
2. Write your name on one colour of scrap paper and place it into the first box. While you do this, your teacher will give you a second, folded piece of scrap paper in a different colour for you to hold on to. Do not open it until you are instructed to do so. This is your vaccination status (vaccinated or unvaccinated). In this round, 10% of your class will be 'vaccinated'. Your teacher will divide the class into three areas: 'Susceptible', 'Infected' and 'Immune'.
3. Write the numbers 1–5 down the side of your index card.
4. Walk up to another student, say hello and shake their hand. Write the name of the student you shook hands with next to the number '1' on the index card.
5. Repeat step 4 with four more students, writing their names in positions 2–5 on the card. When your card is full, stand and wait in the 'Susceptible' area.
6. When everyone is in the 'Susceptible' area, your teacher will draw a name from the box. That student is infected with 'handshake disease'. Handshake disease is contagious and is always transmitted to the next three people you shake hands with, unless you are vaccinated.
7. The student will check their scrap piece of paper from the teacher. If it says 'Vaccinated', they will move to the immune section of the classroom. If it says 'Unvaccinated', they will move to the infected section of the classroom and read out the first three names of the students they shook hands with. If the student drawn is immune, the teacher will select another name from the box.

Figure I2.9: Shake hands with other students in your class and record each person's name next to the numbers 1–5 as you do so to show the order of handshakes.

60 min

8 Any vaccinated students will move to the immune section, and any unvaccinated students will move to the infected section, and read their first three names off the list. This continues until there is no one left in the 'Susceptible' area, and everyone is either immune or cured.

9 Repeat the activity for three more rounds. Each round, the teacher will increase the number of vaccinated individuals in the classroom: 40% in round 2, 70% in round 3, and 95% in round 4.

Questions

1 How many students were infected with handshake disease in round 1? How does this compare to the other rounds?

2 Construct a graph that compares the number of students vaccinated against handshake disease to the number of students infected. (More information about constructing graphs is available in the Science how-to section on pages 457–61.)

3 Describe any patterns or trends that you can see in the graph you have constructed.

4 What inferences can you make from this data about the effect of vaccination on the levels of infectious disease in a population?

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table 12.9: Results

Round	Number of vaccinated students	Number of students infected	Number of students immune
1			
2			
3			
4			

Investigation 2.13

45 min

Infectious diseases and vaccination: data analysis

Process: Analysing data and information

Focus: Describing trends from data

When accessing secondary-sourced information, there can be a lot of available data. It is important to be able to look at data that has been collected and describe any trends in that data.

Hint 1: *What patterns can you see in the data that has been collected?*

Hint 2: *Do these patterns form a consistent trend that you can describe in words?*

Aim

To interpret data relating to the incidence and impact of infectious diseases that can be prevented by vaccination

Materials

- computer with internet access

Method

1. Go to the Australian Institute of Health and Welfare's website and navigate to the page 'Vaccine Preventable Diseases – Fact Sheets' via 'Reports' and 'Immunisation'.
2. Select three disease fact sheets and open the PDFs containing information about them.
3. Review any graphs on the fact sheets for your chosen diseases.
4. Use the graphs and written information on the fact sheets to answer the questions.

Figure I2.13

Questions

1. Identify your three chosen diseases.
2. Describe the trend on each of the graphs on your fact sheets.
3. Explain the link between the trends you have described and the introduction of vaccinations for your chosen diseases.
4. Review three more disease fact sheets and compare any trends you can identify on the graphs with the trends on the graphs of your selected diseases. Can you see any differences?
5. Based on the data you have seen on infectious diseases, assess the impact of vaccinations on those diseases' incidence rate, rate of hospitalisation and rate of death.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim).*'

Investigation 3.1

45 min

Investigating classroom resources

Process: Planning investigations

Focus: Reducing risks in investigations

For all investigations, it is important to use appropriate materials safely and to minimise risk. This investigation requires you to select objects that are available in the classroom. What are some things you should consider before deciding which items to investigate?

Hint 1: *Consider safety, ethics and the environment.*

Hint 2: *Ensure the selected items will allow you to meet the investigation aim.*

Hint 3: *More information about planning investigations is available in the Science how-to section on pages 405–8.*

Aim

To investigate how the resources that are used in common classroom materials are made

Materials

- selection of classroom items (e.g. paper, ruler, eraser, pencil case, calculator, desk, chair, flooring)

Method

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Select up to 10 items in the classroom and add them to your table. Two resources have been added for you.
3. Identify the materials each item is made from. You may need to do some research.
4. Identify how the major material in each item is obtained.
5. Determine whether the item is made from renewable or non-renewable resources.
6. Compare your list with those of others in your class.

Table I3.1: Results

Item	Major resource in item	How is it obtained?	Renewable or non-renewable?
Paper	Paper	Cutting down trees	Renewable
Metal ruler	Aluminium	Mining deposits in rocks	Non-renewable

Questions

1. Identify two risks with conducting this investigation and describe how you could minimise the likelihood of them occurring.
2. Compare the number of renewable resources in your results table to the number of non-renewable resources.
3. Describe the similarities between the items that are made from renewable sources.
4. Describe the similarities between the items that are made from non-renewable resources.
5. Where are most of the non-renewable resources you listed found in nature?

Conclusion

Copy and complete:
‘The model shows that: *(respond to the aim)*.’

Investigation 3.3

Making and mining 'ore'

Process: Planning investigations
Focus: Identifying variables

When asking scientific questions and planning an investigation, you must identify the independent, dependent and controlled variables. The independent variable is what you purposefully change in an investigation. The dependent variable is what you will be measuring. The controlled variables are all the things you need to keep the same throughout the investigation. Identify the variables for this investigation.

Hint: *More information about planning investigations is available in the Science how-to section on pages 405–8.*

Aim

Part A

To make simulated ore from household ingredients

Part B

To investigate the percentage by mass of different 'elements' in the 'ore'

Materials

Part A

- bowl
- Weet-Bix
- teaspoon
- sultanas
- popcorn kernels
- sunflower seeds
- cornflour
- tap water
- baking paper

Part B

- electronic balance
- cupcake liners
- laboratory spatula
- toothpicks

Method

Part A: Making 'ore'

1. In your group, crush one Weet-Bix into a bowl and mix in one teaspoon each of sultanas, popcorn kernels, sunflower seeds and cornflour.
2. Add water slowly while mixing the contents. Stop adding water when the consistency is soft and mushy, but not runny.
3. Mould the mixture into a ball-shaped 'ore' deposit. (You can use your hands, but it will be messy.) Place the ore deposit on a sheet of baking paper.
4. Repeat steps 1–3 until your group has three ore deposits. Allow your ores to dry for at least 24 hours.

Part B: Mining for 'elements'

1. Copy the results table into your notebook, adding a title.
2. Number your ore deposits from Part A.
3. Set the electronic balance to 'zero'. Place your first ore deposit in a cupcake liner, weigh it and record its mass.
4. Using the spatula and/or toothpick, carefully extract the 'elements' from the ore, breaking apart the ore body as needed to ensure all the elements in the ore are found.
5. Place each type of extracted element in separate cupcake liners, weigh each and record the result.
6. Repeat steps 3–5 for your second and third ore deposits.
7. Calculate the average mass of each element for each ore. Use the average mass to calculate the percentage of each element for each of the ore deposits. (More information about calculating averages and percentages is available in the Science how-to section on pages 451–55.)

Questions

1. Identify what was used to simulate ore and elements in this investigation.
2. Identify any variables that were not well controlled and suggest how this could be improved.

20 min
Part A

40 min
Part B
After at least 24 hours

3 Order the elements from lowest to highest percentage by mass of the ore.

4 Compare your results with those of other groups. How did they differ?

5 Assuming that all the elements were equally valuable by mass, which one would be the most profitable? Give a reason for your response.

6 Suggest additional factors to consider when deciding whether to mine Weet-Bix ore. Consider things such as ease of extraction, clean-up, maintaining integrity of the elements, and waste. How do these things relate to the mining industry?

Table 13.3: Results

Element	Mass of element in ore (g)			Average mass (g)	Per cent by mass of element in ore $= \frac{\text{average mass of element}}{\text{average mass of ore}} \times 100$
	Ore deposit 1 (Total mass = ___ g)	Ore deposit 2 (Total mass = ___ g)	Ore deposit 3 (Total mass = ___ g)		
Sultanas					
Popcorn kernels					
Sunflower seeds					

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation 3.8

Properties of pure versus alloy metals

CLASS ACTIVITY/TEACHER DEMONSTRATION

Process: Planning investigations

Focus: Identifying variables

When asking scientific questions and planning an investigation, you must identify the independent, dependent and controlled variables. The independent variable is what you purposefully change in an investigation. The dependent variable is what you will be measuring. The controlled variables are all the things you need to keep the same throughout the investigation. Identify the variables for this investigation.

Hint: *More information about planning investigations is available in the Science how-to section on pages 405–8.*

Aim

Part A

To investigate and compare the properties of pure metals and alloys

Part B (teacher demonstration)

To observe the formation of a solder alloy and compare the melting order of the solder and its metal components

Materials

Part A

- several pairs of substances in elemental and alloy form (e.g. copper metal/brass; iron/steel; silver/bullion; nickel/5-cent coin)
- power supply
- light bulb
- alligator clips
- 100 mL beaker
- 3 connecting wires
- small hammer or pliers
- 50 mL tap water

Part B (teacher demonstration)

- safety glasses
- nitrile gloves and heatproof gloves
- laboratory coat
- 2 g tin foil
- 2 g lead foil
- tripod and clay triangle
- Bunsen burner
- matches
- crucible and tongs
- laboratory spatula
- foil or metal tray
- steel plate
- 1 cm^2 sample of tin
- 1 cm^2 sample of lead
- 1 cm^2 sample of solder (prepared in advance by teacher or technicians)

Method

Part A: Comparing properties of pure vs alloy metals

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Choose one of the pairs of substances and record your observations for the following tests:
   a. **Appearance**: Record the colour, lustre/shine etc.
   b. **Malleability**: Try to bend the sample (malleable, brittle or N/A). You may use a hammer or pliers.
   c. **Hardness**: Scratch the surface of the sample with the other solid samples. Record which ones leave a scratch, to determine relative hardness.
   d. **Conductivity**: Connect the electric circuit as shown in Figure I3.8a. Turn on the power supply to 12 V. Connect alligator clips to either side of the sample to complete the circuit. Observe whether the light bulb turns on.
   e. **Solubility**: Place the sample into the beaker of water. Observe if the sample dissolves or not.

Part B (teacher demonstration): Making an alloy and comparing melting order

Observe your teacher conducting the following tests to explore the properties of lead foil and tin foil and record your observations. Note: The lead foil demonstration will be conducted in a fume cupboard.

⚠ **LEAD IS TOXIC. WEAR GLOVES, AND MAKE SURE THE LABORATORY IS WELL VENTILATED DURING PART B.**

25 min Part A | 15 min Part B

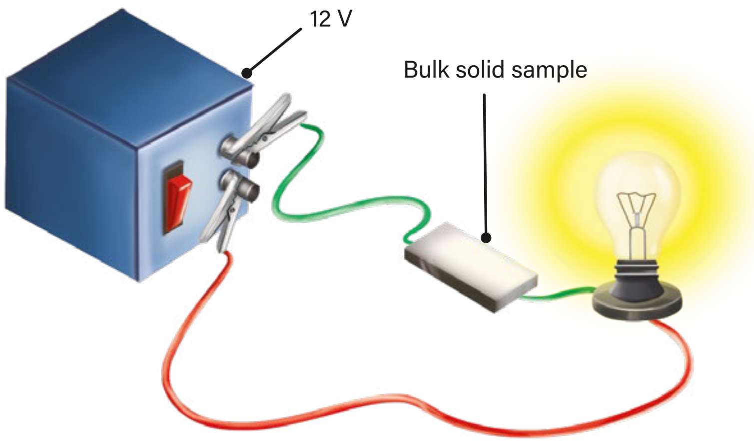
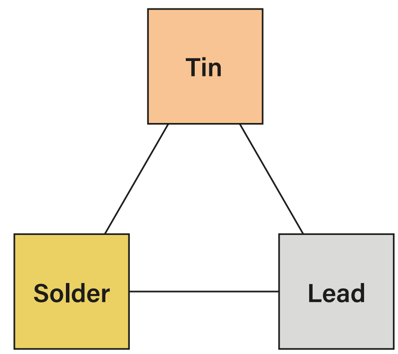


Figure I3.8a: Set-up of the circuit to test conductivity

Figure I3.8b: Arrange the square pieces of lead, tin and solder on the sheet of iron so that they form an equilateral triangle.



Your teacher will conduct the following tests:

1 a Roll the two metal foils together into a ball and place them in a crucible over a flame until they melt.
  b Stir the molten foil with a spatula and remove the oxide layer that forms. Stop heating after 3 or 4 minutes.
  c Using tongs, slowly pour the molten alloy into a metal tray.
  d Flatten the alloy by pressing on it with the head of a spatula or similar object. Allow the alloy to cool further.
  e Students observe and record the appearance and hardness properties of the solder alloy.

2 a Place a square sheet of iron on top of a tripod. Arrange 1 cm^2 pieces of lead, tin and the alloy on the sheet of iron so that they form an equilateral triangle, equidistant from the centre of the Bunsen burner flame. These pieces should lie flat and be the same size and width.
  b Heat the iron sheet exactly in the middle of the triangle from below.
  c Note the order in which the three squares melt. Students record the results.

Questions

1 Identify and describe any trends in the data.

2 Use the metallic bonding model to explain the properties of pure vs alloy metals observed in Part A.

3 In terms of risk, propose why Part B was done as a demonstration.

4 a List the controlled variables that were important in Part B.
  b Describe how each of the controlled variables might have affected the melting order results.

5 Search the theoretical melting temperatures of tin, lead and solder. Discuss how these values compare to the order in which they melted in Part B.

6 Use the metallic bonding model to explain the difference in melting temperatures of pure and alloy metals.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table I3.8: Results

Element	Form	Appearance	Malleability	Hardness	Conductivity	Solubility
e.g. copper	Pure element, e.g. copper wire					
	Alloy e.g. brass					

Investigation 3.10

Student-designed investigation: properties of common substances

Process: Planning investigations

Focus: Planning an investigation that is reliable and valid

You will work in groups of two or three to produce a plan to investigate the properties of common substances. You might choose to investigate many properties of one common substance, or one property of many common substances.

Your student-designed investigation must:

- have a clear aim: What are you trying to find out by conducting the investigation?
- be safe: Identify hazards and describe ways to reduce risk and have a clear aim.
- be valid: The variables must be clearly identified and controlled.

Hint 1: *Consider tests that were conducted in Investigation 3.8.*

Hint 2: *How could you test solubility? Could the dissolved substances also be tested for things like electrical conductivity?*

Hint 3: *If you get stuck, refer to the information on planning investigations in the Science how-to section on pages 405–8.*

Aim

To produce a plan to investigate the properties of common substances

Materials

(Materials will vary for each student group.)

- safety glasses
- laboratory coat
- assorted metallic, ionic and covalent substances:
  - metallic (e.g. copper wire, aluminium foil, magnesium strip, zinc strip, tin foil)
  - ionic (e.g. copper sulfate, sodium chloride, sodium carbonate, calcium carbonate)
  - covalent (e.g. water, sulfur, polystyrene, hard plastic (pen cap vs PVC), sugar, graphite, hydrogen gas (evolves when 0.1 mol L^{-1} HCl and Mg strip are combined), carbon dioxide (evolves when sodium carbonate and vinegar are combined))
- 0.1 mol L^{-1} HCl (acid)
- 0.1 mol L^{-1} NaOH (base)
- white vinegar
- power supply, electrodes, lightbulb, alligator clips
- tap water
- test tube rack
- assorted sizes of beakers, flasks, test tubes and stoppers
- stopper with hole for collection tube
- assorted sizes of measuring cylinders
- glass stirring rod, laboratory spatula, tongs
- thermometer
- watch glass
- electronic balance
- Bunsen burner and matches
- tripod, gauze mat, heat mat
- universal indicator or blue/red litmus paper
- any other materials approved by your teacher

Method

Part A: Producing a plan for the student-designed investigation

1. Explore the materials provided by your teacher. Select the substance(s) and property/properties you would like to explore. Get approval from your teacher. Make adjustments as needed.
2. Write a specific aim for your group's investigation.
3. Identify the independent variable, dependent variable and controlled variables. (More information about variables is available in the Science how-to section on pages 401–4.)
4. List the materials and equipment required to address your investigation aim.

AN OPEN FLAME IS A HAZARD. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND RUN COLD WATER OVER THE AFFECTED AREA FOR 20 MINUTES.

DISPOSE OF WASTES APPROPRIATELY.

45 min
Part A

45 min
Part B

5 Identify the hazards associated with the required materials. Describe ways to reduce the risks for each of the hazards you have identified. Include disposal of waste; for example, copper sulfate cannot go down the sink.

6 Write a step-by-step procedure to address the investigation aim that is detailed enough for a classmate to follow.

7 Construct a results table, following the model in Table 13.10a. Be sure to include units where needed, and indicate if multiple trials are required.

8 Get final approval from your teacher.

Table 13.10a: Investigation variables

Independent variable (What will you change?)	Dependent variable(s) (What will you measure, and how?)	Controlled variables (What will you keep the same, and how?)

Table 13.10b: Risk assessment

Hazardous substances and equipment	Describe the hazard	Describe ways to reduce risk	Describe what to do if an accident occurs

Table 13.10c: Results

	DV (unit)	DV (unit)	DV (unit)
IV			
IV			

Part B: Carry out the investigation

9 Review your procedure and risk assessment before collecting your materials.

10 Follow your procedure, including safety measures, and record the data in your results table.

11 With support from your teacher, make adjustments to the procedure as needed.

12 Share your results with other groups in the class.

13 Complete the questions below.

Questions

1 a Based on the properties observed, classify the substances that were investigated as metallic, ionic or covalent.

b Conduct a search to determine the true classification of the substances tested. Were there any that did not match your predictions? Propose reasons for any differences.

2 Some tests are not easy to carry out in a school setting. List additional tests that might support the investigation of the materials that were explored.

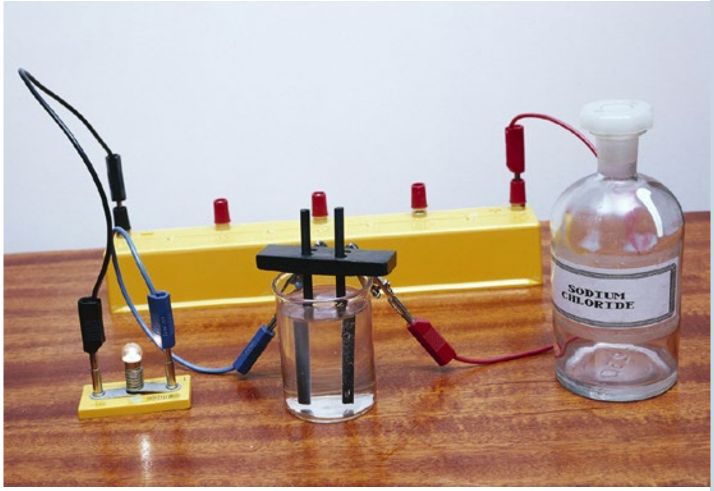
3 How well were you able to control the controlled variables? Discuss this in relation to the validity of your results.

4 Other than by practical means in the laboratory, propose ways you might be able to classify the materials provided.

5 For each of the substances tested in the investigations, identify links between their properties and how they are commonly used in daily life.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'



▲ **Figure 13.10:** An electrical circuit can be used to test the conductivity of common substances when they are dissolved in water.

Investigation 3.13

Modelling organic compounds

Process: Communicating
Focus: Constructing presentations on findings
When scientists conduct first-hand and second-hand investigations, they need to be able to communicate the results appropriately to their audience. Good presentations often include both first- and second-hand data, to support the information they are providing.
Hint 1: *Where could you find additional information about representing organic compounds?*
Hint 2: *How will you show your audience that the information you are providing is in your own words? (More information about referencing is available in the Science how-to section on page 443.)*

Aim

To explore a range of ways to represent organic compounds

Materials

- 20 × toothpicks
- playdough or plasticine:
  - black represents carbon
  - white represents hydrogen
  - red represents oxygen

Note: Molymod kits can be used as an alternative to plasticine and toothpicks.

Method

1. Copy the results table into your notebook, including the given structural formulas.
2. Build a three-dimensional model to represent the first organic compound (CH_4). (Hint: The structural formula is two-dimensional because it is drawn on flat paper. But at the atomic level, pairs of electrons spread out as much as possible around each atom, so your models should be three-dimensional.)
3. Sketch each model, taking into consideration the three-dimensional perspective. (Hint: Solid lines represent bonds that are parallel with the paper. Dotted lines represent bonds going into the paper, and bold wedged lines indicate bonds coming out of the paper.) Examples for CH_4 are shown in Table I3.13.
4. Complete the rest of the columns in the table for the first organic compound.
5. Repeat steps 2–4 for each compound in the table. You or your teacher may choose to provide more compounds to model.

Questions

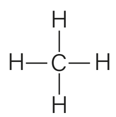
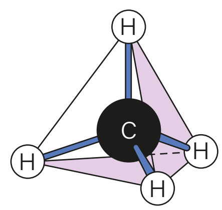
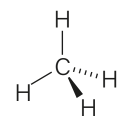
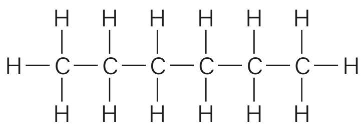
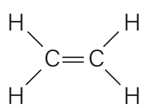
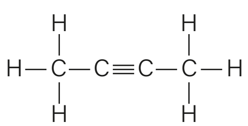
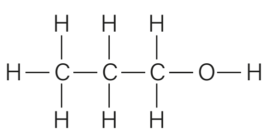
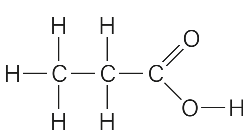
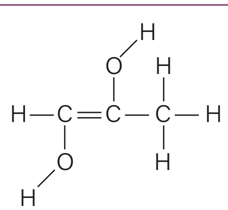
1. Identify what all the carbon atoms have in common in each of your models.
2. Write the condensed structural formula for each compound modelled in this investigation.
3. Identify a difference between the structural formulas and your models. How can structural formulas be improved to better represent real molecules?
4. Identify compounds with the same molecular formula. Use this to explain why it is important to use structural formulas to represent organic compounds.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

30 min

Table 13.13: Results

Structural formula	3D sketch of model	Molecular formula	Organic class	IUPAC* name
	 			
				
				
				
				
				
				1,2-prop-1-enediol

Note: *International Union of Pure and Applied Chemistry.

Investigation 3.15A

Complete and incomplete combustion reactions

Process: Planning investigations

Focus: Developing an aim

Every investigation should have a clear aim. What are you trying to accomplish by conducting the investigation? The aim for this investigation is quite broad. After reading the method, rewrite the aim to include more detail to show links between the theory and the purpose of this investigation.

Hint 1: *How are the results of this investigation important in a wider context?*

Hint 2: *More information about planning investigations is available in the Science how-to section on pages 405–8.*

Aim

To observe complete and incomplete combustion reactions

Materials

- safety glasses
- tap water
- Bunsen burner
- matches
- thermometer
- tripod
- gauze mat
- retort stand
- rubber stopper with hole
- 2 × 250 mL beakers
- stopwatch
- heatproof mat
- bosshead and clamp

Method

1 Copy the results table into your notebook, adding a title.

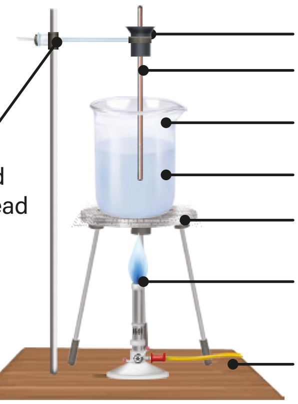


Figure I3.15A: Set-up of the equipment

2 Set up the equipment as shown in Figure I3.15A.

3 Record the initial temperature of the water.

4 Light the Bunsen burner and, with the collar almost closed, heat the water for 5 minutes.

5 Record the final temperature and find the change in temperature.

6 Observe the bottom of the beaker to see if any soot (black substance) formed.

7 Replace the beaker of water and repeat steps 3–5 with the collar fully open.

Questions

1 Describe an observation you made about the bottom of the beaker after each combustion reaction was complete.

Table I3.15A: Results

Reaction	Flame colour	Soot or no soot	Initial temperature (°C)	Final temperature (°C)	Temperature change after 5 min (°C)
Incomplete combustion					
Complete combustion					

30 min

2 Identify any particles you found on the beakers.
3 Describe the difference in the colour of the flame in complete and incomplete combustion. Explain why this was the case.
4 Explain the difference between complete and incomplete combustion.
5 Write word and formula equations for the complete combustion of methane.
6 Write word and formula equations for the incomplete combustion of methane.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation 3.15B

Combustion of fuels

Process: Planning investigations

Focus: Identifying variables

When asking scientific questions and planning an investigation, you must identify the independent, dependent and controlled variables. The independent variable is what you purposefully want to change in an investigation. The dependent variable is what you will be measuring. The controlled variables are all the things you need to keep the same throughout the investigation. Identify the variables for this investigation.

Hint: *More information about planning investigations is available in the Science how-to section on pages 405–8.*

Aim

To determine which fuel (ethanol, propanol or butanol) combusts to produce the most energy over time

Materials

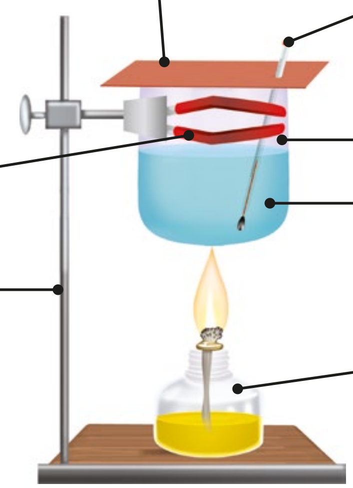
- safety glasses
- spirit burners: ethanol, propanol and butanol (50 mL each)
- matches
- tap water
- 100 mL measuring cylinder
- thermometer
- stopwatch
- retort stand
- calorimeter or metal can
- insulating card or lid
- tripod and gauze mat
- heatproof mat
- bosshead and clamp

⚠ **FUELS ARE FLAMMABLE. BE CAREFUL NOT TO SET THEM ALIGHT.**

Method

1 Copy the results table into your notebook, adding a title.

2 Set up the equipment as shown.



3 Fill the calorimeter with 100 mL of water. Fill the spirit burner with 50 mL of ethanol.

4 Record in the results table the initial temperature of the water.

5 Light the spirit burner and record the time taken for the temperature of the water to increase by 10 °C.

6 Extinguish the flame with the cap of the spirit burner.

7 Check and record if the bottom of the metal can or calorimeter has soot on it.

8 Repeat steps 3–7 with propanol and butanol.

9 Record all your observations.

Questions

1 Identify the controlled variables, independent variable and dependent variable.

2 Describe how you could improve the reliability of your results.

45 min

Table I3.15B: Results

Fuel	Initial temperature (°C)	Final temperature (°C)	Change in temperature (°C)	Time for water temperature to increase by 10 °C (minutes)	Soot or no soot
Ethanol					
Propanol					
Butanol					

3 Identify the products of combustion of the fuel sources.
4 Explain which fuel source was the most efficient.
5 List some assumptions (things you took for granted) that could have interfered with your results.
6 Is it possible for combustion to occur without oxygen? Justify your response.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation 3.16

30 min

Polymers in the environment

Process: Planning investigations

Focus: Reducing risks in investigations

No matter the investigation, using appropriate materials safely and minimising risk is important. This investigation requires you to select objects that are available in the classroom. What are some things you should consider before deciding what items to investigate?

Hint 1: *Consider safety, ethics and the environment.*

Hint 2: *More information about planning investigations is available in the Science how-to section on pages 405–8.*

Aim

To investigate the quantity and types of polymers found in the schoolyard

Materials

- clipboard
- survey sheet
- pencil or pen

Method

1. Copy the results table onto a sheet of paper. This is your survey sheet. Add rows as needed throughout the investigation. Fix this sheet to a clipboard to make it easier to record results.
2. Walk around all areas of the schoolyard, recording all items or materials you think are polymers. If you come across the same item more than once, use the tally column to record how many of a particular item you see.
3. Record any additional comments or details about the items you see.
4. Return to the classroom and conduct research to identify any unidentified items and to determine whether they are polymers.
5. Compare your list with those of others in your class.

Questions

1. How many different types of polymers did you record?
2. Describe the similarities and differences between the items on your survey sheet.
3. Was there an area of the schoolyard that had more polymer items than others? Propose a reason for why this might be the case.
4. a Which polymer had the most tally marks?
   b What type of polymer is this?
   c Conduct an internet search to determine how long it will take for this type of polymer to break down.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table I3.16: Results: survey sheet

Item/material	Tally	Comments (e.g. location)	Polymer (Y/N)	Type of polymer

20 min 20 min
1–3 weeks apart

Biodegradability of packaging

Process: Problem-solving
Focus: Proposing solutions to scientific problems
The inability of plastics to break down has created a problem for our society. Some of the best properties of polymers in terms of use are also their worst properties with regards to the environment. The aim of this investigation is to determine the biodegradability of a range of packaging materials. Based on the results, you should be able to propose a range of possible solutions to the problems plastics create for our society.
Hint: More information about problem-solving is available in the Science how-to section on pages 425–28.

Aim
To explore the biodegradability of various types of packaging

Materials
- 4 types of packaging materials (e.g. cling wrap, bioplastic, assorted BioPak items, polystyrene)
- electronic balance
- composting container and soil (including worms and/or microorganisms)
- tap water

Method
1 Copy the results table in your notebook, adding a title and rows as necessary.
2 Test how resistant each material is to tearing and record the results. This is a relative measurement, which means it depends on the material. Give the easiest-to-tear material a 'low' rating, and the materials that do not tear easily a 'high' rating.
3 Weigh about 1 gram of each packaging material and record the 'before' mass.
4 Bury the samples (spread out) in a bucket of composting soil. Map the positions of each type of packaging, as shown in Figure I3.17Aa.
5 Sprinkle the bucket with 100 mL of water each day for 1–3 weeks (depending on types of packaging and time available).

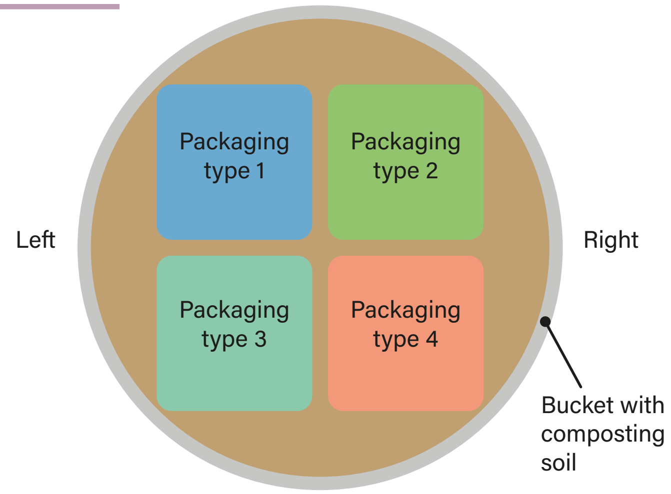


Figure I3.17Aa: Create a map of the positions of each type of buried packaging.

6 After the packaging has been buried for a certain amount of time, dig up each packaging sample and repeat the resistance and mass tests.
   a Clean off as much compost material as possible and weigh the sample. Record the 'after' mass.
   b Repeat step 2 and record any changes in its resistance to tearing. Is it the same, more resistant or less resistant?
7 Share your results with other groups in your class.

Questions
1 Identify the packaging material that is the most biodegradable with reference to the results. Identify the packaging material that is the least biodegradable.
2 Describe any unexpected results. Propose reasons for why the results might be unexpected.
3 Propose the type of polymer that each type of packaging is made of. Explain your answer.
4 Biodegradability is often measured in terms of carbon dioxide production, which requires specialised equipment to measure. Explain how measuring resistance and mass is a good alternative.

Conclusion
Copy and complete:
'The results show that: *(respond to the aim)*.'

continues ▶

Table I3.17A: Results

Packaging type	Resistance to tearing (relative)		Mass (g)			Additional observations
	Before (low, med, high)	After (less, same, more)	Before	After	Difference in mass = before – after	
1						
2						

Figure I3.17Ab: The composting soil should be moist with plenty of microbes and/or worms.

25 min

Properties of 'Ghostbuster' slime

Process: Problem-solving

Focus: Explaining scientific problems

There is usually a cause for a particular scientific problem, which has an effect on a given population. This investigation explores one way a polymer can be modified to alter its properties. However, possible solutions to the problem may also have unwanted effects on society. This investigation helps you to consider challenges faced by scientists when addressing scientific problems with cause-and-effect relationships.

Hint: More information about problem-solving is available in the Science how-to section on pages 425–28.

Background theory

Polyvinyl alcohol (PVA) is an addition polymer that is soluble in water. This makes it easy to add weak cross-links of borax to a PVA solution, as shown in Figure I3.17Bb.

Borax interacts with the –OH functional groups of PVA, forming weak cross-links between polymer chains and trapping water molecules throughout the substance. The cross-links can break and re-form easily, resulting in properties similar to 'Ghostbuster' slime.

Aim

To observe the changes in the physical properties of a polymer when weak cross-links are added

Materials

- safety glasses
- nitrile gloves
- 50 mL 6% polyvinyl alcohol (PVA)
- paper cup
- green (or other colour) food dye
- 10 mL 4% borax (sodium borate) solution
- wooden ice-cream stirring stick

BORAX AND PVA CAN BURN EYES. WEAR SAFETY GLASSES AND GLOVES. WASH YOUR HANDS AFTER HANDLING THEM. DO NOT CONSUME THE SLIME.

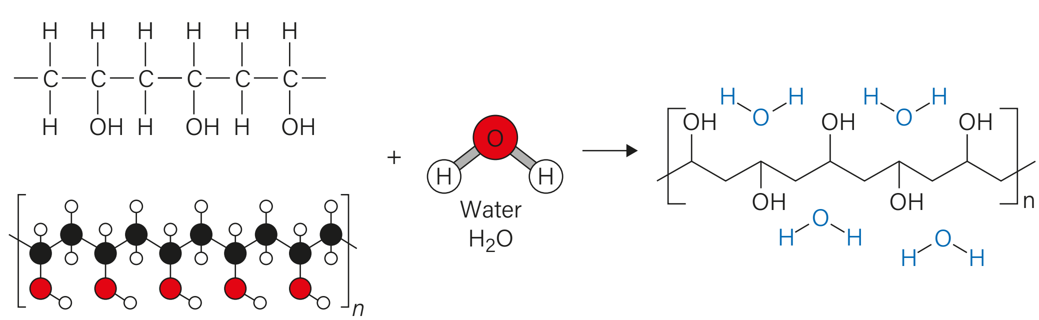


Figure I3.17Ba: When PVA is added to water, water molecules surround the polymer, dissolving the PVA.

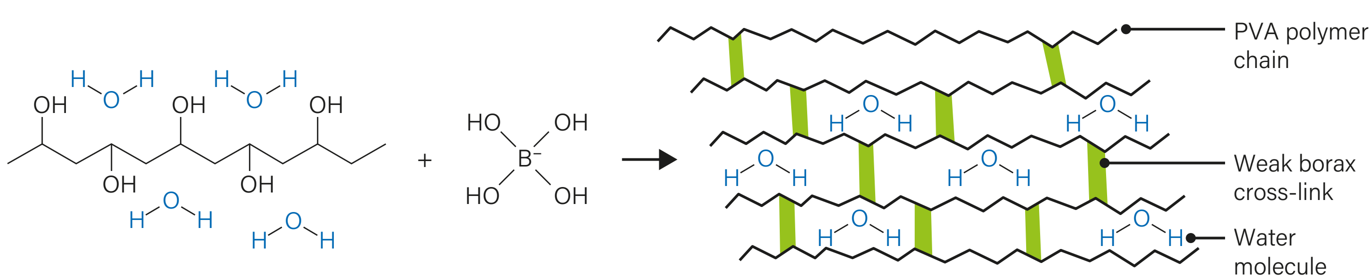


Figure I3.17Bb: Borax forms cross-links between the polymer chains and traps water molecules.

continues ▶

Method

1 Copy the results table into your notebook, adding a title.
2 Measure 50 mL of 6% PVA solution into the paper cup.
3 Add a few drops of food colouring and stir with a wooden stick.
4 Add 10 mL of 4% borax solution. Begin stirring immediately. A gel should form.
5 Take some in your hand and slowly stretch it. Record your observations.
6 Now stretch the gel very quickly. Record your observations.
7 Test additional properties as appropriate and record your observations.

Questions

1 a Identify the monomer used to form polyvinyl alcohol (PVA).
  b Draw its structural formula.
  c Name the monomer according to IUPAC nomenclature.
2 Describe the physical properties that change when borax is added to the PVA.
3 Propose the effect of adding more borax to the slime.
4 Propose how the physical properties of the slime would change if the cross-links were covalent bonds. Discuss the implications.
5 Explain how water might contribute to the physical properties of the slime.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table I3.17B: Results

Polymers	Texture	Stretch slowly	Stretch quickly	Bounceability	Viscosity	Additional observations
Polyvinyl alcohol						
'Ghostbuster' slime						

Investigation 3.19

30 min

Comparing drinking straws

Process: Problem-solving

Focus: Explaining scientific problems

There is usually a cause for a particular scientific problem that has an effect on a given population. This investigation explores possible solutions to a problem that has an impact on the environment. However, possible solutions to the problem may also have unwanted effects on society. This investigation will help you to explain the challenges faced by scientists when addressing scientific problems with cause-and-effect relationships.

Hint: *More information about problem-solving is available in the Science how-to section on pages 425–28.*

Aim

To investigate a variety of straws made from materials other than traditional plastic

Materials

- straws that are not made of plastic (e.g. paper, metal, silicon, bamboo, polylactic acid (PLA))
- 4 × 50 g slotted masses and a 50 g mass carrier
- 250 mL beaker
- ice
- tap water
- stopwatch
- kettle or urn per class

HOT WATER IS A HAZARD. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND RUN COLD WATER OVER THE AFFECTED AREA FOR 20 MINUTES.

Method

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Record general observations for each straw: colour, texture, size, circumference.
3. Test the strength of each straw.
   a. Place the straw horizontally over a gap between two tables or chairs.
   b. Loop the yarn around the middle of the straw and hang the 50 g weight in the middle of the straw.
   c. Add weights until the straw bends in half and record the weight. If the straw never bends, record '>250 g'.
4. Test each straw's durability in ice water.
   a. Fill the beaker with ice and add water.
   b. Stir the ice water for 1 minute.
   c. Record your observations during and after the 1 minute.
5. Repeat step 4 with dry straws and in hot water instead of ice water.
6. With approval from your teacher, you may choose to conduct additional tests to observe other properties. Add columns to the results table as needed.

Questions

1. Propose which property you tested that you feel is the most important for drinking straws. Provide a reason.
2. Describe how the length and/or circumference of the straw might affect the drinking experience.

Table I3.19: Results

Drinking straw material	General observations (colour, texture, size, circumference)	Strength (g)	Durability in water		Additional property to test (if any)
			Ice water	Hot water	
Paper					

continues ▶

3 Identify your preferred material for a drinking straw to ensure a pleasant drinking experience. Provide a reason with reference to specific results.

4 Discuss which material you think is the most environmentally friendly.

5 Many factors need to be considered with deciding on the 'best' material to replace plastic drinking straws, such as consumer experience and environmental impacts. Rank the materials in order from most appropriate to least appropriate alternative drinking straw material. Explain the ranking with reference to results and specific examples.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation 4.1

30 min

The sustainability game

Process: Problem-solving

Focus: Evaluating solutions to a problem

Evaluation can help you to identify the best way to solve a problem. Think about the problem and the outcome that needs to be achieved. Consider all the different solutions and use evidence that agrees or disagrees with each of them.

In this investigation, after you have completed the activity, evaluate the different strategies used and identify the one that is most effective.

Hint: *When you evaluate, you need to make a judgement and provide evidence to support your judgement.*

Aim

To demonstrate how to use a resource so that it can continue to be used in the future

Materials

- 60 marbles per group
- container

Method

The aim of the game is to collect the most marbles at the end of eight rounds.

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Count out 20 marbles into the container (your 'source'), leaving the others as reserves.
3. Decide how many marbles you will remove from the source. The number of marbles you remove at each round can only vary by one. For example, if you remove three marbles in round 1, you can take two or four out in round 2.
4. At the end of each round, add one marble from the reserves for every four marbles left in the source. For example, if 16–19 marbles are left, you should add four. If 1–3 marbles are left, you should not add any.
5. Continue removing and adding marbles until you run out of marbles in the source or make it through eight rounds. Record your results in your table.
6. Construct a graph of your results. Plot the number of marbles taken on the *y*-axis and the number of rounds on the *x*-axis. (More information about drawing graphs is available in the Science how-to section on pages 457–61.)

Questions

1. Compare your results to those of other groups. Who collected the most marbles at the end of eight rounds? Who collected the least? Did anyone run out of marbles from the source before the end of eight rounds?
2. Evaluate the different strategies that were used. What strategies allowed for a sustainable use of the resource? What strategies were not sustainable? Why?
3. Did the marbles in this game represent a renewable or non-renewable resource? Justify your response.
4. How would the rules and outcome of the game have been different for the other type of resource?

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table I4.1: Results

Round	Number in source at start of the round	Number removed from source	Number left in source	Number added to source at end of round

Investigation 4.3

30 min

Observing the weather

Process: Analysing data and information

Focus: Representing data to identify patterns and trends

Choosing how to represent your data so that it can be clearly communicated to someone reading your investigation report is an important skill. In this investigation, turn your data into a chart or a graph. Identify any patterns or trends in your data and include this in your discussion.

Hint: *There are many ways to visualise your data, such as bar charts, line graphs and pie charts. Make sure you choose the best one for your dataset.*

Aim

To make observations over a period of one week and relate these to the weather observed

Materials

For entire group:

- thermometer
- barometer
- rain gauge
- hygrometer
- anemometer
- ruler

Method

1. Determine where you will take your readings over the next week.
2. The day before you begin, make sure the rain gauge is set up according to the instructions.
3. Copy the results table into your notebook, including space for the weather measurements you will make.
4. Temperature: Use the ruler to measure 1 m above the ground. Hold the thermometer at this point until the reading settles. Record the temperature in the results table.
5. Humidity: Set up the hygrometer according to the instructions. Hold it, or set it up, so it hangs 1 m above the ground. Record the humidity in the results table.
6. Air pressure: Set up the barometer according to the instructions. Record the air pressure in the results table.
7. Wind speed and direction: Set up the anemometer according to the instructions. Record the wind speed and direction in the results table.
8. Rain: Measure the volume of water in the rain gauge, then dispose of any rain collected to reset the gauge. Record the volume in the results table.
9. Cloud cover: Describe the amount of cloud cover (perhaps as a percentage of the sky covered).
10. Other observations: Record other observations you can make about the weather.
11. Consider the best way to represent your raw data. (More information about drawing graphs and constructing tables is available in the Science how-to sections on pages 457–61 and 412–13.)

Questions

1. Use the Bureau of Meteorology website to find the weather observations for your location over the same period. Compare these with your observations.
2. Evaluate the data you gathered with reference to its accuracy and reliability.
3. Suggest how you could improve the data you gathered with reference to accuracy and reliability.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Table I4.3: Results

Date	Time	Temperature (°C)	Humidity (%)	Air pressure (hPa)	Wind speed (km h^{-1})	Wind direction	Rain in the last 24 hours (mm)	Observations	
								Cloud cover	Other

Investigation **4.4**

60 min

The greenhouse effect

Process: Analysing data and information

Focus: Assessing results for reliability and validity

If you repeat an investigation many times and get the same results, it means they are reliable. A large amount of variation can indicate that the results are not reliable.

'Validity' refers to how well the data addresses the experimental aim. Is the independent variable the only thing that is influencing the dependent variable? Or do more factors need to be controlled?

Hint 1: *Repeating your experiment multiple times can help to assess the reliability of the data.*

Hint 2: *Carefully controlling all variables except for the independent and dependent variables can help to ensure your data is valid. (More information about variables is available in the Science how-to section on pages 401–4.)*

Aim

To investigate how a greenhouse affects air temperature

Materials

- 200 mL conical flask
- rubber stopper with hole
- sticky tape
- 2 thermometers
- Blu-Tack or plasticine
- stopwatch

Method

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Seal the conical flask by placing a rubber stopper into the top of it. This is your greenhouse.
3. Place the thermometer through the hole in the rubber stopper and seal in place with Blu-Tack to stop it from touching the bottom of the flask.
4. Place your greenhouse outside in direct sunlight. Place the second thermometer next to the greenhouse, using Blu-Tack or plasticine to support it. Make sure the thermometer bulb does not touch any surface.
5. Record the initial temperature of both thermometers.
6. Record the temperature of both thermometers every minute for 20 minutes.
7. Quickly cover or remove the greenhouse and thermometers from sunlight.
8. Continue to record the temperature every minute for a further 20 minutes.

Questions

1. Identify the independent, dependent and controlled variables in this investigation.
2. Create a graph of your results.
3. Describe the difference between the temperature inside and outside the greenhouse when it was placed in sunlight to warm.

Table 14.4: Results

In sunlight			Out of sunlight		
Time (minutes)	Temperature (°C)		Time (minutes)	Temperature (°C)	
	Internal greenhouse	External to greenhouse		Internal greenhouse	External to greenhouse

continues ▶

4 a Describe the difference between the temperature inside and outside the greenhouse when out of the sunlight.

b Explain how this is similar to the greenhouse effect caused by greenhouse gases.

5 a Identify any variables that should have been controlled in this investigation.

b How would these have affected the results? Suggest changes to the method that would have ensured these were controlled.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation 4.7A

60 min

Modelling thermal expansion

Process: Analysing data and information

Focus: Representing data to identify patterns and trends

Choosing how to represent your data so that it can be clearly communicated and easily analysed is an important skill. In this investigation, after you have collected and recorded your data in the results table, turn the data into a chart or a graph.

Hint 1: *Think about the best type of graph to illustrate your data. (More information about drawing graphs is available in the Science how-to section on pages 457–61.)*

Hint 2: *What trends are evident in your data from your graphs?*

Aim

To investigate how water expands when heated

Materials

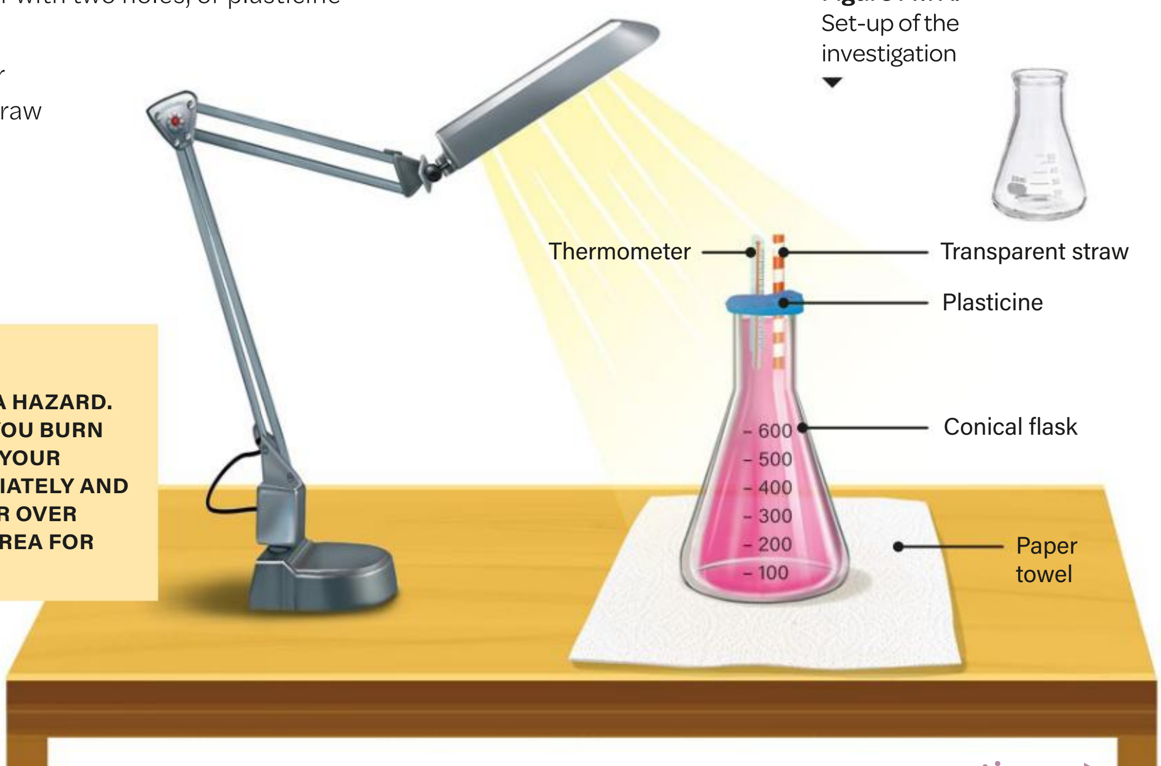
- 600 mL conical flask or bottle
- paper towel
- food colouring (optional)
- rubber stopper with two holes, or plasticine
- thermometer
- glass tubing or transparent straw
- marker
- heat lamp
- stopwatch
- 30 cm ruler

A HEAT LAMP IS A HAZARD. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND RUN COLD WATER OVER THE AFFECTED AREA FOR 20 MINUTES.

Method

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Place the flask or bottle on the paper towel. Place a few drops of food colouring in the flask before filling it with water to the top.
3. Carefully place the thermometer and tubing/straw in the flask so that at least 5 cm sits within the flask and 5 cm sits above. Use the stopper or the plasticine to help you keep it in place. Some of the water will overflow.
4. Ensure there are no gaps and that no water can leak out.
5. Use the marker to mark the water level in the straw. This will be your zero mark.
6. Measure the starting temperature of the water and record it in the results table.
7. Place the bottle underneath the heat lamp and turn it on.

Figure I4.7A: Set-up of the investigation



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8 Measure and record the water level in the straw and the temperature of the water every 5 minutes for 30 minutes.

9 Construct a suitable graph for your data.

Table I4.7A: Results

Time (minutes)	Water level (mm)	Temperature (°C)

Questions

1 Identify the dependent, independent and controlled variables for this investigation. (More information about variables is available in the Science how-to section on pages 401–4.)

2 Describe the trends in your data.

3 Compare your results with those of your classmates. Discuss the reliability of your data.

4 Use your findings from this investigation to explain how warmer ocean temperatures also result in sea-level rise.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation 4.7B

30 min

Melting ice and sea-level rise

Process: Analysing data and information

Focus: Evaluating statements based on data

When you evaluate, you need to make a judgement and provide evidence to support your judgement. Data can provide evidence that can support or refute a statement or a claim.

Hint: *Refer to specific data when you are making a judgement on a statement.*

Aim

To model how melting sea ice and melting glaciers contribute to sea-level rise

Materials

- 2 × 500 mL beakers or containers
- clay or plasticine
- 8 ice cubes
- marker
- heat lamp
- ruler

Method

1. Copy the results table into your notebook, adding a title.
2. Place a lump of clay or plasticine in one beaker; this will model a continent. Model it so there is a platform for the ice cubes to sit on. The top of the 'continent' should sit just above the 200 mL mark.
3. Place four ice cubes (the glacier) on the 'continent' and add four ice cubes to the second beaker (to model sea ice).
4. Add water to both beakers up to the 200 mL mark or to the same height.
5. Use the marker to mark the initial water level in both beakers.
6. Place both beakers under the heat lamp until the ice melts.
7. Use the marker to record the new water level in both beakers.
8. Use a ruler to measure the initial water level and the final water level. Calculate the change.

Table I4.7B: Results

Beaker	Initial water level (mm)	Final water level (mm)	Change in water level (mm)
Sea ice			
Glaciers			

Questions

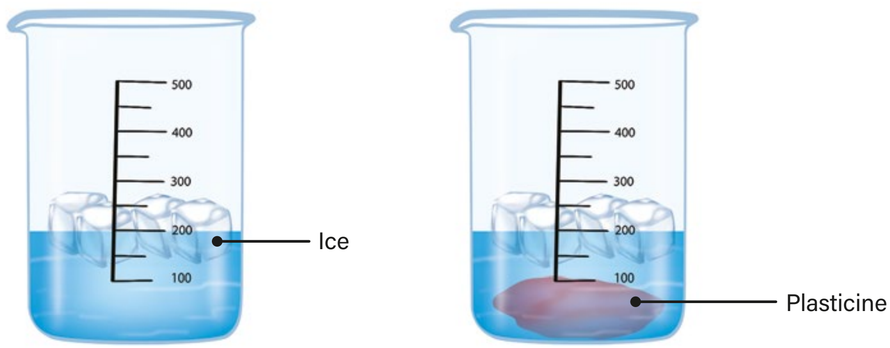
1. Describe your results. Compare your results with those of other groups.
2. Explain any differences in the results between the beaker that represented sea ice and the beaker that represented glaciers.
3. What does this model tell you about how melting glaciers and sea ice contributes to sea-level rise?
4. Consider the headline 'Melting Arctic sea ice causes sea-level rise'. Use your understanding to suggest an improvement to the headline.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Figure I4.7B: Set-up of the investigation



Investigation 4.8

Modelling ocean acidification

Process: Analysing data and information

Focus: Assessing data for reliability and validity

If you repeat an investigation many times and get the same results, it means they are reliable. A large amount of variation can indicate that the results are not reliable.

'Validity' refers to how well the data can address the experimental aim. Is the independent variable the only thing that is influencing the dependent variable? Or do more factors need to be controlled?

***Hint 1:** Repeating your experiment multiple times can help to assess the reliability of the data.*

***Hint 2:** Carefully controlling all variables except for the independent and dependent variables can help to ensure your data is valid. (More information about variables is available in the Science how-to section on pages 401–4.)*

Aim

To model the effect of ocean acidification on organisms with calcium carbonate shells

Materials

- 50 mL of solutions of 5%, 10%, 15%, 20% and 25% acetic acid
- distilled water
- 6 × 100 mL beakers
- 1 × 50 mL measuring cylinder
- 6 seashells of identical type and shape *or* eggshells (you may need to use pieces of broken shell)
- electronic balance
- marker
- paper towel

Method

1 Copy the results table into your notebook, adding a title and rows as needed.

2 Label the beakers 0%, 5%, 10%, 15%, 20% and 25%.

3 Use a measuring cylinder to measure 50 mL of distilled water. Place it in the 0% beaker.

4 Use the measuring cylinder to measure 50 mL of each of the acetic acid solutions into each beaker. Rinse the cylinder between each use.

5 Identify which beaker each shell will go into. Use the electronic balance to weigh each shell. Record this in the results table, taking care not to mix up the shells.

6 Place the shells in their corresponding beakers.

7 Leave the shells in the beakers for 3 days.

8 Remove the shells from the beakers and place them on labelled paper towel to dry for 2 days.

9 When the shells are dry, measure their mass on the electronic balance. Record this in the results table.

10 Calculate the mass change:
initial mass – final mass = mass change

11 Calculate the percentage mass change:
$\frac{\text{mass change}}{\text{initial mass}} \times 100$

12 Construct a graph of your results.

Questions

1 Identify the dependent, independent and controlled variables in this investigation.

2 Describe the trends in your results.

3 Explain how this investigation models the process of ocean acidification.

Table I4.8: Results

Concentration of acid (%)	Initial mass of shell (g)	Final mass of shell (g)	Mass change (g)	Per cent mass change $\frac{\text{mass change}}{\text{initial mass}} \times 100$

30 min	5 days	30 min
Initial set-up	Leave shells in beakers for 3 days. Remove and dry for 2 days	Complete mass calculations

4 Discuss the importance of calculating the percentage mass change to ensure your data is reliable.

5 Evaluate the method. Did it allow you to collect valid and reliable data? Redesign the method to improve the validity and reliability of your data. (More information about validity and reliability is available in the Science how-to section on pages 423–24.)

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation 4.12

30 min

Making bioplastic

Process: Problem-solving

Focus: Evaluating claims based on evidence

Scientific evidence is useful when evaluating a claim that has been made. When evaluating the claim, you need to consider all the scientific evidence that will support or refute the claim.

Hint: *When you evaluate, you need to make a judgement and provide evidence to support your judgement.*

Aim

To investigate how plastic is made, using cornflour

Materials

- hotplate
- 250 mL beaker
- tablespoon
- teaspoon
- cornflour
- vinegar
- vegetable glycerine
- water
- stirring rod
- aluminium foil
- spatula
- selection of commercially produced plastics

Method

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Set up the hotplate.
3. Add 1 tablespoon of cornflour, 1 teaspoon each of vinegar and glycerine, and 4 tablespoons of water to the beaker. Stir with the stirring rod until combined.
4. Place the beaker onto the hotplate and switch it on to low heat.
5. Continue stirring the solution until it thickens and starts to become translucent. This will not take long!
6. Carefully pour the plastic onto a sheet of aluminium foil and spread it using the spatula.
7. Allow the plastic to completely cool. This will take several hours. If you wish to form the plastic into another shape, leave it spread out on the foil to cool for approximately 1 hour. It can then be carefully moulded into shape before it sets completely.
8. Compare the flexibility of your plastic with the samples provided. Record your observations.
9. Take a piece of your plastic and add it to water. Record your observations.
10. Take a piece of your plastic and heat it in a beaker over the hotplate. Record your observations.

Table I4.12: Results

Material	Flexibility	Behaviour in water	Behaviour when heated

Questions

1. Describe the properties of your bioplastic.
2. Compare these properties to the properties of some conventional plastics.
3. What happened when you added your bioplastic to water?
4. What happened when you reheated your bioplastic?
5. Explain the benefit of using a bioplastic, such as the one you have made, compared to a conventional plastic.
6. Use evidence gathered from this investigation to evaluate the claim that this bioplastic should be used in the place of conventional plastics in commercial applications.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim).*'

BE CAREFUL USING THE HOTPLATE. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND RUN COLD WATER OVER THE AFFECTED AREA FOR 20 MINUTES.

Investigation 5.1

45 min

Extracting DNA from strawberries

Process: Communicating

Focus: Presenting scientific findings

The methods and findings from a first-hand investigation should be able to be presented clearly for someone reviewing the work you have done. Consider how you could visually represent the processes and results of this investigation.

Hint 1: *What scientific equipment are you using, and how can you use diagrams to represent its setup?*

Hint 2: *Refer to 'Using scientific equipment' in the Science how-to section on pages 463–67 for help with your representations.*

Aim

To investigate the process of extracting DNA from strawberries

Materials

For each class:

- liquid dishwashing detergent
- salt
- electronic balance
- tap water
- 50–100 mL measuring cylinder

For each group:

- plastic spoon
- strawberries
- zip-lock bag
- large test tube
- test tube rack
- funnel
- 10 cm square of Chux cloth
- 30 cm ruler
- plastic pipette
- very cold ethanol (kept in on ice or in the freezer)
- 10 mL measuring cylinder
- wooden skewer

Method

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Make the DNA extraction buffer (this can also be pre-prepared by a lab assistant). Add 5 mL of detergent, 0.75 g of salt (weighed on an electronic balance) and 45 mL of water to the larger measuring cylinder. Stir to mix. This will make enough for five 10 mL samples of extraction buffer.
3. Remove the green stem of a strawberry and wash the strawberry carefully with water.
4. Place the strawberry in a zip-lock bag with 10 mL of the extraction buffer and remove as much air as possible before sealing the bag tightly.
5. On the bench, crush and massage the strawberry inside the bag for a minute.
6. Set up the test tube in a rack on the bench.
7. Place the funnel in the test tube and then line the funnel with the gauze.
8. Pour the mixture from the zip-lock bag into the funnel.
9. When the mixture has filtered (this will take some time), discard the gauze and strawberry pulp, keeping only what was filtered into the test tube.
10. Measure the amount of liquid in the test tube very roughly with a ruler.
11. Use the plastic pipette to add the same amount of ice-cold ethanol as the amount of liquid already in the test tube.
12. Observe what happens in the test tube. You should be able to see changes straight away.
13. Use the wooden skewer to gentle remove some DNA from the top of the test tube.

Questions

1. Describe the appearance of the strawberry DNA.
2. How does this compare to the description of DNA in spread 5.1?
3. Propose why it was important to crush the strawberry before extracting the DNA.
4. Construct a diagrammatic flow chart, showing the processes involved in the extraction, that could be used by another student to complete the practical.

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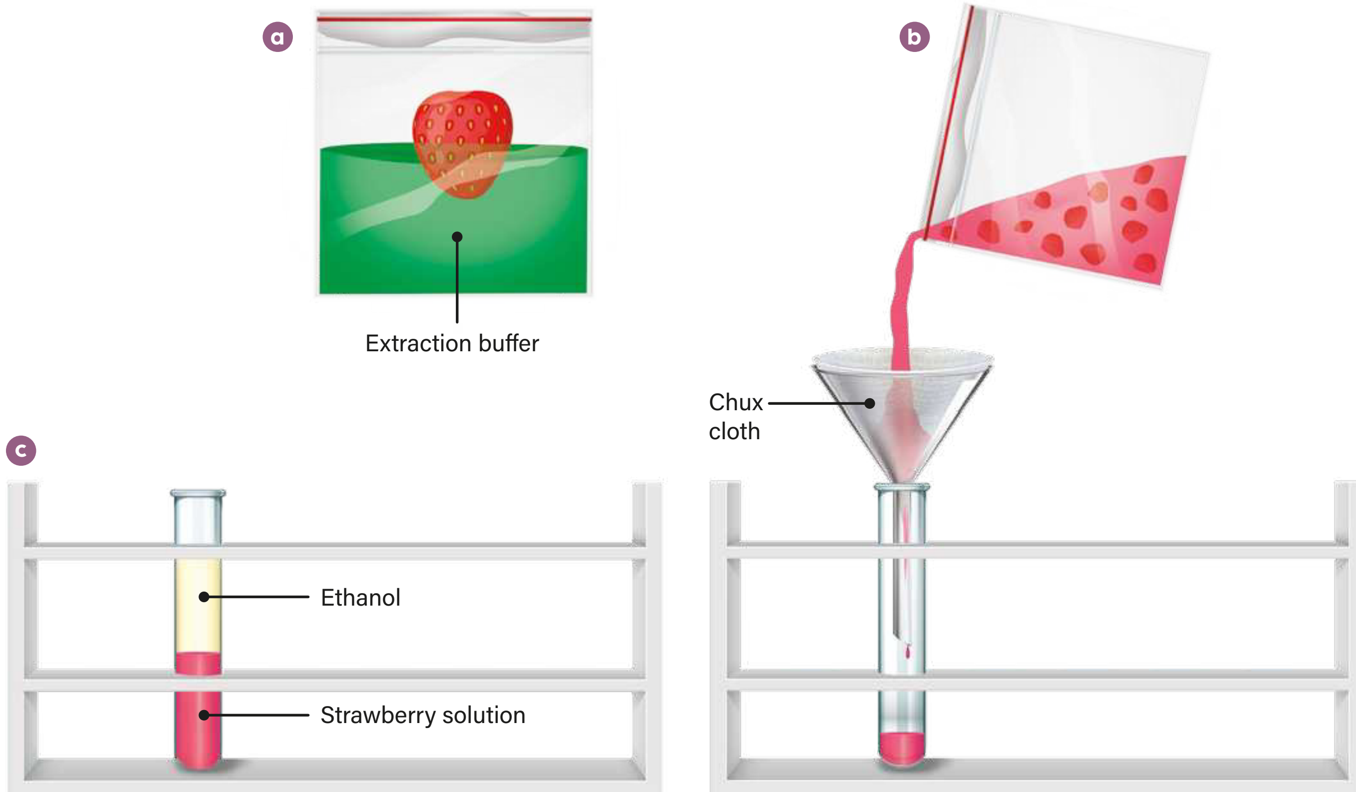


Figure 15.1: Thoroughly crush the strawberry before filtering it.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table 15.1: Results

Observations	Photo or diagram

Investigation 5.3

30 min

DNA lolly model

Process: Communicating

Focus: Selecting ways to present information

When presenting concepts to others, scientists often look at what they are presenting before deciding on the format they are going to use. Why would a model be appropriate when presenting information about the structure of DNA?

***Hint:** Think about the size and location of DNA molecules.*

Aim

To investigate the structure of DNA by making a model out of lollies

Materials

- 2 long red liquorice straps
- 4 of the same type of lollies in 4 different colours (e.g. mini-marshmallows, jelly beans, gummy bears)
- toothpicks
- clean surface or cutting board
- small pieces of paper

Method

1. Assign lolly colours to each of the four DNA bases: adenine, cytosine, guanine and thymine.
2. Use two pieces of red liquorice as the DNA backbone.
3. Pair your lolly bases: guanine with cytosine and adenine with thymine.
4. Thread the matching base pairs onto toothpicks.
5. Insert the ends of the toothpicks into the red liquorice DNA backbone.
6. Twist the red liquorice DNA backbone as you go, creating the DNA twisted double helix model.
7. Use the paper and toothpicks to label each of the four bases and the sugar–phosphate backbone of your DNA model.
8. Draw a diagram or take a photo of your finished DNA model.

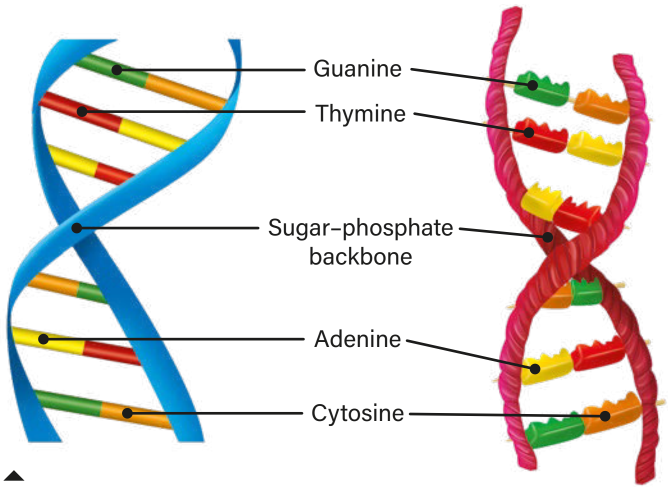


Figure I5.3: Remember to organise your four colours into two pairs and always put them next to one another between the two liquorice ladders.

Questions

1. Propose why the use of models in science is important.
2. Outline why this model of DNA is useful for presenting to others when explaining the structure of DNA.
3. Explain how your model demonstrates the features and arrangement of a molecule of DNA inside a cell.
4. Discuss one way you could improve this model to make it more accurate. (Hint: Think about the backbone.)

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation 5.6

30 min

Genetic trait survey

Process: Communicating

Focus: Organising information using digital technologies

A table is a simple way to organise data and information that is collected during a first-hand investigation. Digital technologies make it easier to construct these tables to collate information, and to construct other visual representations of your results such as a graph.

Hint: *What computer software could allow you to easily construct a results table?*

Aim

To investigate the different genetic traits that exist in a population

Materials

- genetic trait survey
- at least 10 participants
- laptop

Method

1. Construct a digital version of the results table on your laptop or device.
2. In the second column of the table, record whether you have the genetic trait listed in the first column.
3. Share your results with the rest of the class and construct a class tally.
4. Copy the class tally into your digital table.

Questions

1. Digitally graph your class results for each trait. (More information about graphs is available in the Science how-to section on 457–61.)
2. Identify the most and least prevalent traits in your class.
3. Propose two more genetic traits you could have checked for.
4. Propose why some traits are more common than others.
5. Genetic traits are passed down from parents on chromosomes. Describe the structure of a chromosome.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Table I5.6: Results

Trait	My response (yes or no)	Total number in class
Curly hair		
Brown eyes		
Attached earlobe		
Cleft chin		
Hitchhiker's thumb		
Ability to roll tongue		
Left-handedness		
Widow's peak hairline		

Investigation 5.12

30 min

Natural selection in practice

Process: Processing data and information
Focus: Constructing appropriate graphs
When you write a formal investigation report, there is always a results section that includes your data, often as a table, chart or image. Choosing how to represent your data so that it can be clearly communicated to someone reading your investigation report is an important skill. In this investigation, after you have collected and recorded your data in the results table, turn the data into a chart or a graph. Identify any patterns or trends in your data and include this in your discussion.
Hint 1: There are many ways to visualise your data, such as bar charts, line graphs and pie charts. Make sure you choose the best one for your dataset.
Hint 2: More information about selecting an appropriate graph type is available in the Science how-to section on pages 457–61.

Aim

To investigate the effectiveness of different 'beaks' in collecting different types of food

Materials

- marbles
- uncooked rice
- string (cut into 3 cm pieces)
- popcorn kernels
- 4 small plastic tubs
- forceps
- crucible tongs
- kitchen tongs
- blunt pliers
- stopwatch
- 4 paper cups
- graph paper

Method

1. Copy the results table into your notebook, adding a title.
2. Place the marbles, rice, pieces of string and popcorn into each of the plastic tubs (i.e. marbles in one tub, rice in another tub, etc.).
3. Designate a different 'beak' (forceps, crucible tongs, kitchen tongs or blunt pliers) to each person in the group.
4. Choose a person to use the stopwatch to time 30 seconds.
5. Each student uses their tool to pick up as many objects in one of the tubs as possible in the 30 seconds. For example, the student with the forceps attempts to pick up items from the marble container, the student with the crucible tongs attempts to pick up items from the rice container. Participants place the objects they collect with their tool into their paper cup.
6. After 30 seconds, stop and count how many of each object is in each person's paper cup.
7. Record the totals in your results table.
8. Share your data so that each person can complete their results table.
9. Each student returns their items to the plastic tub.
10. Repeat steps 4–9 three more times. For each turn, students move to the next plastic tub and try to pick up a different item using the same instrument.

Questions

1. Define 'natural selection'.
2. Explain how this investigation demonstrates the principles of natural selection.
3. Identify the 'beak shape' that was the best for picking up each type of food and propose a reason for why this was the case.
4. Construct a graph of your results table to visually represent your collected data.
5. Describe the type of graph you chose to represent your data and justify your choice.

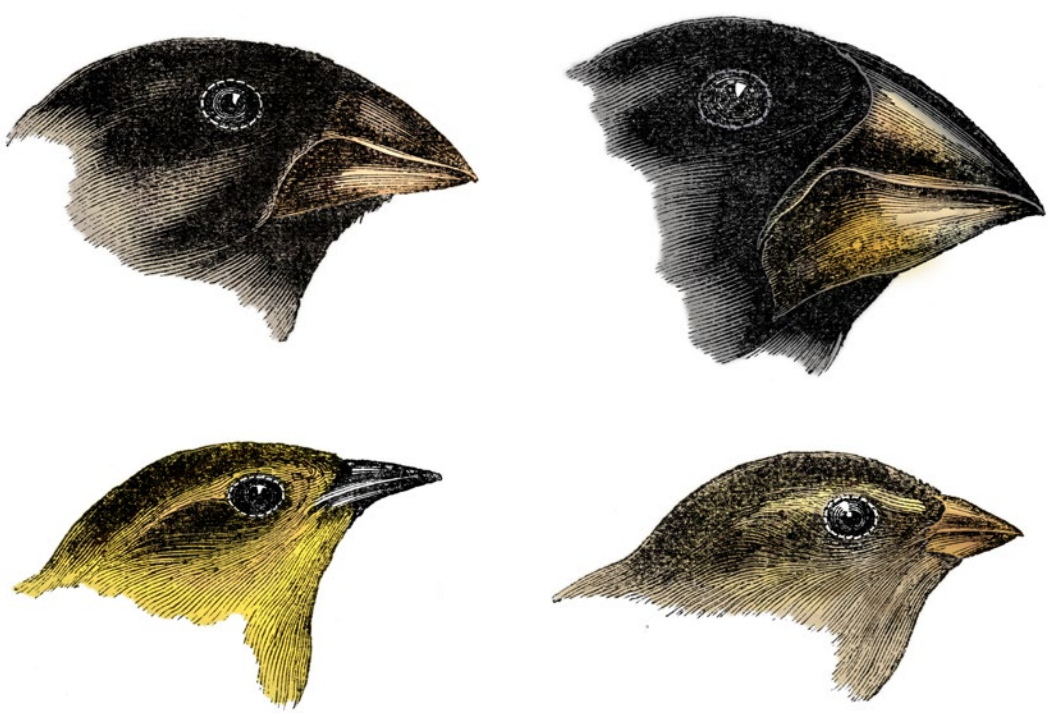
Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

continues ▶

Table 15.12: Results

Tool	Beak type	Number of pieces of string	Number of grains of rice	Number of popcorn kernels	Number of marbles
Forceps 	Long, thin, pointy				
Crucible tongs 	Long, medium width, pointy				
Kitchen tongs 	Long, wide				
Blunt pliers 	Short, thick, wide				



Investigation **5.13A**

30 min

Dating fossils

Process: Processing data and information

Focus: Organising data with tables and graphs

Graphs are a great way to visually represent data from a table to show the results of a first-hand investigation. Constructing graphs allows scientists to easily detect trends in data. The data from the table in this investigation can be represented as a graph.

Hint: *Which type of graph would be appropriate for the data collected? (More information about selecting an appropriate graph type is available in the Science how-to section on pages 457–61.)*

Aim

To investigate a model for absolute dating

Materials

- 100 × 5- or 10-cent coins in a container

Method

1. Each coin represents an atom in the radioactive element carbon-14. You will be investigating how long the half-life of carbon-14 is. Scientists can calculate the age of fossils by identifying the half-lives of atoms surrounding the fossil.
2. Copy the results table into your notebook, adding a title.
3. Shake the container and carefully empty the coins onto the table. Spread them out so that none overlap.
4. Remove all the coins showing tails. These represent atoms that are no longer radioactive and have decayed.
5. Record the number of coins showing heads in your results table. These represent atoms that are still radioactive.
6. Put the coins showing heads back in the container. Shake the container, and carefully empty the coins onto the table. Repeat this process until all the coins are gone or you have completed 12 trials.

Table I5.13A: Results

Shake number	Number of coins showing heads (radioactive atoms)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	

Questions

1. Describe how this investigation models the process used to date fossils.
2. Identify the number of shakes it took for approximately half of your coins to decay. This is the half-life of your coins.
3. The half-life of carbon-14 is 5730 years. If each coin shake represents one half-life, calculate the number of years it would take for carbon-14 to completely decay.
4. Explain what your results told you about absolute dating and the decay of radioactive isotopes.
5. Construct an appropriate graph showing the decay rate of your coins.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Investigation 5.13B

30 min

Comparative anatomy

Process: Processing data and information

Focus: Using data to support hypotheses

Scientists often use models to represent concepts so that they can be easily seen and interpreted. Use the models shown to support or refute the hypothesis: 'Comparative anatomy provides evidence showing that species must have diverged from a common ancestor.'

Hint: *More information about structuring a response that supports or refutes evidence is available in the Science how-to section on page 444.*

Aim

To investigate the comparative anatomy of humans, cats, whales and bats

Materials

- images of human, cat, whale and bat appendages (or full skeletons/models if possible)
- coloured pencils

Method

1. Consider the diagrams of the homologous structures of a human, a cat, a whale and a bat in Figure I5.13Ba.
2. Copy the diagram into your notebook or obtain a photocopy from your teacher.
3. Colour each ulna the same colour on each of the four appendages.
4. Continue to colour the same bones on each appendage in matching colours. Label the bones.
5. Create a Venn diagram, like the one in Figure I5.13Bb, in your results section that shows the similarities and differences between each species appendage, based on your observations.

Questions

1. Identify bones that are common to all four species.
2. Describe the function of each of the structures shown in the diagram. What do they tell you about the organisms they come from?
3. Based on your analysis of the structures, support or refute the statement: 'Comparative anatomy provides evidence showing that species must have diverged from a common ancestor.'
4. Explain how comparative anatomy is used to provide evidence supporting evolution.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

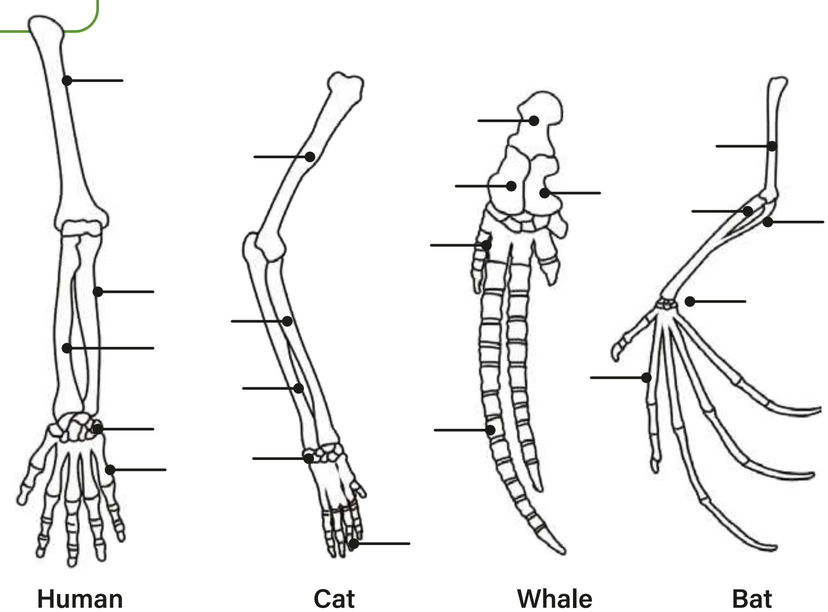


Figure I5.13Ba: The structure of a human arm, cat leg, whale fin and bat wing

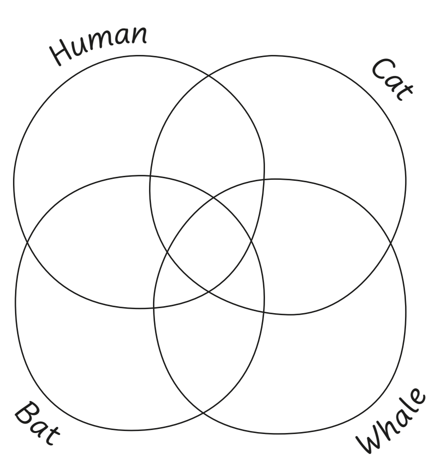


Figure I5.13Bb: Results

Investigation **6.1**

30 min

Investigating the law of conservation of mass

Process: Observing

Focus: Using scientific tools to make observations

Tools used in an investigation help to collect a range of observations. Identify and describe the tools used in this investigation. What other tools could be used to enhance observations to meet the aim of this investigation?

Hint 1: *Think about conservation of mass and apply it to the observations made in this investigation.*

Hint 2: *More information about making observations is available in the Science how-to section on pages 398–400.*

Aim

To investigate the law of conservation of mass in open and closed systems

Materials

- safety glasses
- nitrile gloves
- 2 × 5 g marble chips (calcium carbonate)
- 2 × 100 mL conical flasks
- 2 × 10 mL of 2 mol L^{-1} hydrochloric acid (HCl)
- 10 mL measuring cylinder
- balloon
- electronic scales
- stopwatch

Method

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Weigh about 5 g of marble chips into the first conical flask (flask A).
3. Measure 10 mL of 2 mol L^{-1} HCl into a measuring cylinder.

2 MOL L^{-1} HYDROCHLORIC ACID IS CORROSIVE. WEAR SAFETY GLASSES AND GLOVES. AVOID CONTACT WITH SKIN. IF HCL CONTACTS SKIN, RINSE IMMEDIATELY. WASH YOUR HANDS AFTER THIS INVESTIGATION

4. Place flask A on the scales. Pour in the hydrochloric acid and record the maximum mass observed at time zero (0 minutes). Start a 10-minute timer.
5. Swirl flask A for 2–3 seconds every 30 seconds and record the mass every minute for 10 minutes.
6. Measure about 5 g of marble chips into the balloon. (You can do this without using the scales by estimating a similar amount used in flask A.)
7. Measure 10 mL of 2 mol L^{-1} HCl into flask B.
8. Place flask B on the scales and put the balloon over the top, without letting the chips fall into the flask. Record the maximum mass observed at time zero (0 minutes).
9. Lift the end of the balloon, allowing the chips to fall into the conical flask. Start a 10-minute timer.
10. Swirl flask B for 2–3 seconds every 30 seconds for 10 minutes.
11. Compare your results to other groups in your class.

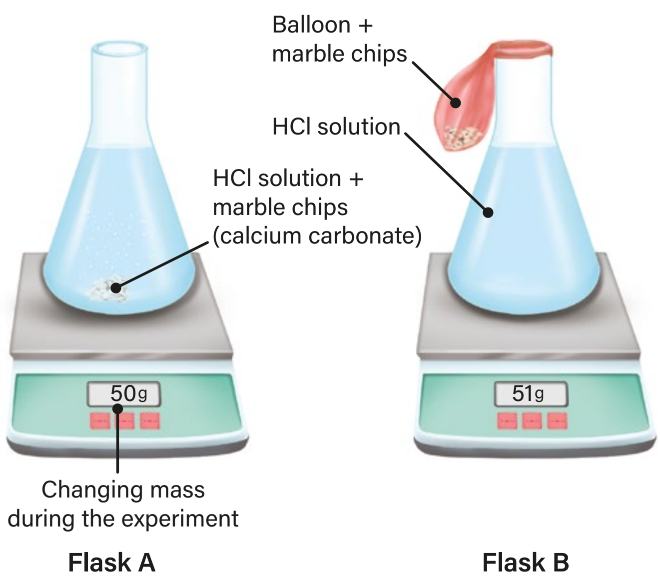


Figure I6.1: Place the balloon on the flask a in a way that allows you to record the mass before the reaction begins.

continues ▶

Questions

1. Propose which flask represents a closed system. Provide a reason with reference to observations.
2. a. Describe any trends in the data observed for flask A and flask B.
   b. Identify the tool(s) used to collect your observations.
3. Evaluate the following statement: 'I was able to record observations and measurements accurately.'
4. Explain how mass is conserved even for the flask without the balloon.
5. Propose how the equipment could be improved to collect more precise observations.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table 16.1: Results

	Mass (g) of conical flask, marble chips and HCl (and balloon) at:										
	0 min	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Flask A											
Flask B (with balloon)											

Investigation 6.3

30 min

Simulating chemical reactions

Process: Observing

Focus: Using scientific tools

Tools used in an investigation help to collect a range of observations. Identify and describe the tools used in this investigation. What other tools could be used to enhance observations to meet the aim of this investigation?

Hint 1: *Think about conservation of mass and apply it to the observations made in this investigation.*

Hint 2: *More information about making observations is available in the Science how-to section on* *pages 398–400.*

Aim

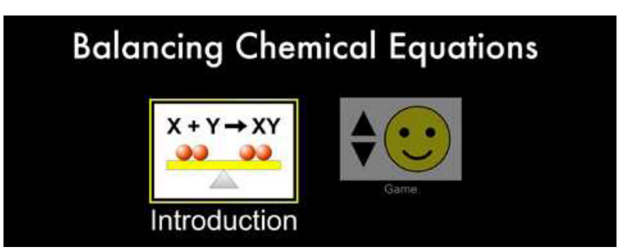
To model chemical reactions that demonstrate the law of conservation of mass by adjusting the coefficients in a chemical equation

Materials

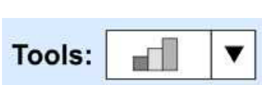
- device with capabilities to run PhET simulation
- PhET simulation 'Balancing Chemical Equations'

Method

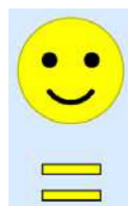
1. Copy the results table into your notebook, adding a title and rows as needed.
2. Go to the PhET website and navigate to the 'Balancing Chemical Equations' simulation.
3. Select the 'Introduction' simulation.



4. Ensure the 'Make Ammonia' simulation is ticked and select the columns icon under 'Tools'.



5. Identify the chemical formula for each reactant and product of this reaction and record this in the results table. (This has been done for you as an example.)
6. Click the Up arrow to increase the coefficient of each of the reactants and products to '1'. Record the coefficient and total atoms in the results table. (This has been done for you as an example.)
7. Adjust the coefficients for the reactants and product until the number of each type of atom on the reactants side is equal to the number of each type of atom on the products side.



8. Try using the measuring scales icon under 'Tools' as another way to balance the atoms.

9. Once you have balanced the equations, record the coefficients and total atoms in the results table.
10. Repeat steps 4–8 for the 'Separate Water' and 'Combust Methane' simulations and construct appropriate results tables to record the results.
11. Once you have balanced all three simulated chemical reactions, click the 'Game' icon at the bottom of the screen. Start with level 1 and see how far you get!

continues ▶

Questions

1 Write the balanced chemical equation to represent each of the simulations.

- **a** Make ammonia
- **b** Separate water
- **c** Combust methane

2 **a** Identify the features or tools included in the simulation that helped you to balance the chemical equations.

- **b** Describe the observations you made that helped you to balance the chemical equations.
- **c** Summarise your approach to balancing chemical equations.

3 Describe why it is important to balance chemical equations when representing chemical reactions. (Hint: What law must be demonstrated?)

4 When magnesium metal (Mg) reacts with hydrochloric acid (HCl), it forms magnesium chloride salt ($MgCl_2$) and hydrogen gas molecules (H_2). Explain why you cannot adjust the subscript numbers of the chemical formulas to balance chemical equations. Use examples to support your response.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Table 16.3: Results

Simulated reaction →	Make ammonia			Observations and comments
	Reactant + Reactant → Product			
Chemical formulas	N_2	H_2	NH_3	The law of conservation is not yet demonstrated because there are not enough nitrogen atoms and too many hydrogen atoms on the product side for the amount of reactants.
Coefficients	1	1	1	
Total atoms	N = 2	H = 2	N = 1 H = 3	
Coefficients				
Total atoms				

Investigation 6.4A

40 min

Synthesis of iron oxide

Process: Planning investigations

Focus: Reducing risks in investigations

Using appropriate materials safely and taking steps to minimise risk is important for every investigation. This investigation requires a variety of materials, equipment and processes. What are some things you should consider before starting the investigation?

Hint 1: *Consider safety, ethics and the environment.*

Hint 2: *More information about planning investigations is available in the Science how-to section on pages 405–8.*

Aim

To investigate the conditions required for the rusting of iron

Materials

- safety glasses
- nitrile gloves
- 5 test tubes
- test tube rack
- laboratory spatula
- drying agent such as calcium hydroxide
- tap water
- salt water
- boiled water
- 5 ungalvanised iron nails
- electronic balance
- oil
- 5 rubber stoppers
- 2 × 10 mL measuring cylinders
- masking tape
- marker
- paper towel

Method

1. Copy the results table into your notebook, adding a title.
2. Read all the instructions before you begin this experiment.
3. Set five test tubes in a test tube rack.
4. Label the first test tube 'Air only'.
5. Label the second test tube 'Drying agent'. Add one spatula of calcium hydroxide.
6. Label the third test tube 'Water and air'. Add 10 mL of tap water (or enough to cover a nail).
7. Label the fourth test tube 'Salt water'. Add 10 mL of salt water (or enough to cover a nail).
8. Label the fifth test tube 'Oil and boiled water'. Add 10 mL of boiled water (or enough to cover a nail).
9. Weigh the five nails separately. Note each mass and add a nail to each test tube, ensuring that each is covered by water or the drying agent.
10. Add oil to cover the boiled water in test tube 5.
11. Stopper all test tubes with the rubber stoppers.
12. Observe the test tubes every second day for a week.
13. Remove the nails, clean and dry them, and weigh them.
14. Record all your results in the results table.

Questions

1. With reference to data, rank the nails from the least rusted to the most rusted.
2. Predict whether there should have been a gain or a loss in mass of the nails. Explain.
3. a Which environment causes the most rust?
   b Research why this environment causes the most rusting of iron.
4. Propose why it was important to measure the mass of the iron nail before and after the experiment.
5. Explain how a nail rusting is an example of a synthesis reaction. Provide a word equation or chemical equation to support your response.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

WEAR SAFETY GLASSES AND GLOVES WHILE DOING THIS EXPERIMENT TO PREVENT RUSTED METAL FROM ENTERING YOUR EYES OR TOUCHING YOUR SKIN.

continues ▶

Table 16.4A: Results

	Test tube				
	1 Air only	2 Drying agent	3 Water and air	4 Salt water	5 Oil and boiled water
Initial mass of nail (g)					
Final mass of nail (g)					
Change in mass (g)					
Observations					

Investigation 6.4B

40 min

Decomposition of copper(II) carbonate

Process: Planning investigations

Focus: Developing an aim

Every investigation should have a clear aim. What are you trying to accomplish by conducting the investigation? The aim for this investigation is quite broad. After reading the method, rewrite the aim to include more detail to show links between the theory and the purpose of this investigation.

Hint 1: *How are the results of this investigation important in a wider context?*

Hint 2: *More information about planning investigations is available in the Science how-to section on pages 405–8.*

Aim

To observe the decomposition of a metal carbonate

Materials

- retort stand
- bosshead and test tube clamp
- 3 g copper(II) carbonate
- electronic scales
- 2 large test tubes
- test tube rack
- stopper with delivery tube
- Bunsen burner
- heat mat
- matches
- 25 mL measuring cylinder
- 15 mL limewater (calcium hydroxide)
- black paper or card

AN OPEN FLAME IS A HAZARD. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND RUN COLD WATER OVER THE AFFECTED AREA FOR 20 MINUTES.

DISPOSE OF WASTES APPROPRIATELY.

Method

1 Copy the results table into your workbook, adding a title and rows as needed.

2 Set up the apparatus as shown in Figure I6.4B.

3 Weigh about 3 g of copper(II) carbonate into test tube A. Record the mass of the test tube and copper(II) carbonate.

4 Return test tube A to the retort stand, adjusting the clamp so the test tube is at an angle. Stopper test tube A with a stopper that has an attached delivery tube.

5 Measure about 15 mL of limewater into test tube B and place it in the test tube rack. Place the black paper behind test tube B. (This will help you to observe any changes during the reaction.)

6 Submerge the end of the long tube in the limewater, so it is close to the bottom of test tube B.

7 Light the Bunsen burner and position the flame under the copper carbonate. Record your observations.

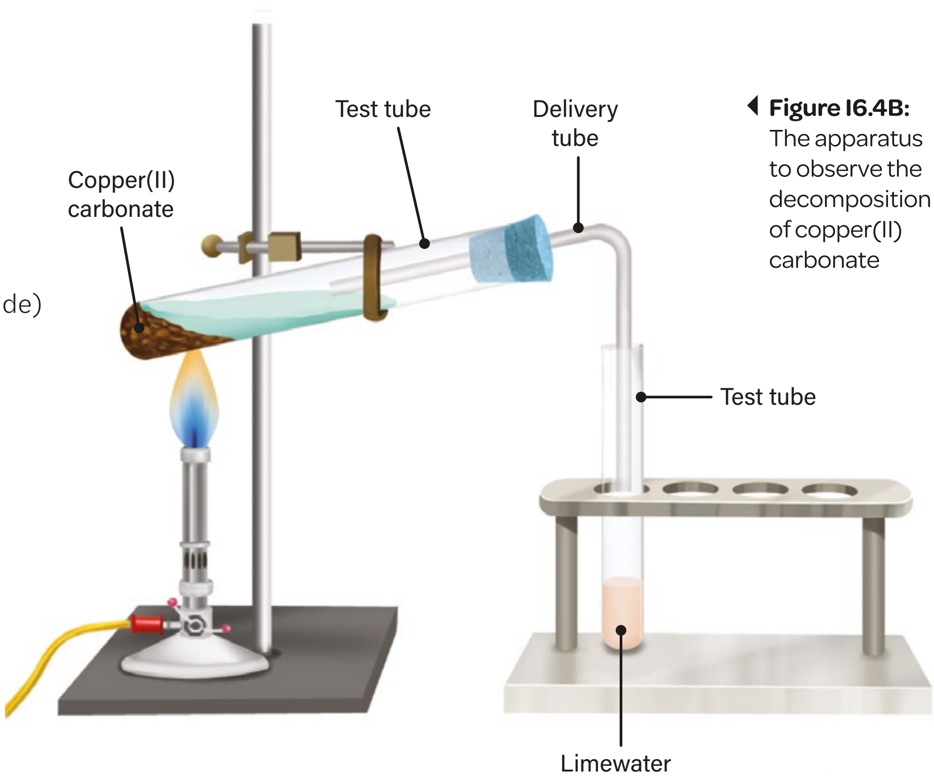


Figure I6.4B: The apparatus to observe the decomposition of copper(II) carbonate

continues ▶

8 After 1–2 minutes, or when the reaction appears to be complete, turn off the Bunsen burner and remove the tube from the limewater.

9 Once cooled, reweigh test tube A, including its contents.

10 Share your results and observations with other groups in the class.

Questions

1 State the observations that indicate that a chemical reaction is taking place.

2 Summarise the experimental observations that indicate this is a decomposition reaction.

3 Describe the purpose of bubbling the gaseous product through the limewater.

4 a Propose the purpose of the flame in this investigation.

b Predict whether the reaction will occur without the flame. Provide a reason.

5 The limewater turns white because calcium carbonate (an insoluble salt) and water form when carbon dioxide reacts with calcium hydroxide.

a Write a word equation to represent this reaction.

b Write a skeleton equation for this reaction.

c Write a complete and balanced chemical equation to represent this reaction. (Hint: You may have to refresh skills from previous sections.)

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table I6.4B: Results

Groups	Mass of test tube A and copper carbonate (g)		Additional (dot-point) observations (e.g. colour change, limewater, change in mass)
	Before	After	
Group 1			

Investigation **6.5A**

15 min | 1–2 days | Observation

Growing metallic crystals: metal displacement reactions

Process: Questioning and predicting

Focus: Making predictions based on scientific knowledge

To formulate a testable hypothesis, you must first identify the independent, dependent and controlled variables. The independent variable is what you purposefully change in an investigation. The dependent variable is what you measure. The controlled variables are all the things you need to keep the same throughout the investigation. To formulate your hypothesis, use the following sentence stem: It can be hypothesised that if *(something to do with your independent variable)*, then *(something to do with your dependent variable)*, because *(reference to scientific concepts)*.

Hint 1: *More information about questioning and predicting is available in the Science how-to section on pages 401–4.*

Hint 2: *In your conclusion, state whether your hypothesis was supported (correct) or rejected (incorrect).*

Background information

Some metals are more reactive than others. When a piece of solid metal is placed in a solution of less reactive metallic ions, the solid metal reacts to form dissolved ions, and the ions react to form solid metallic crystals. This is an example of a single-displacement reaction:

Magnesium (s) + aluminium chloride (aq) → magnesium chloride (aq) + aluminium (s)

Aim

To investigate single-displacement reactions by growing metallic crystals from ionic compounds

Materials

- safety glasses
- nitrile gloves
- laboratory coat
- 30 mL fresh, warm agar solution (Tech note: 1.6 g agar/100 mL water.)
- 10 mL measuring cylinder
- 10 mL of 0.1 mol L^{-1} ionic solution of one of silver nitrate, tin chloride, copper sulfate
- 5 mL lead nitrate
- 1 cm × 4 cm strip of clean zinc, copper, magnesium or aluminium
- petri dish and lid

Method

1. Copy the results table in your notebook, adding a title and rows as needed.
2. Your group will be allocated one ionic solution and one strip of metal. Write these in your results table. Predict whether a reaction will occur.
3. Measure 10 mL of your allocated ionic solution into a 10 mL measuring cylinder.
4. Measure 30 mL of warm agar solution into a petri dish.
5. Immediately pour 10 mL of the ionic solution gently into the petri dish.
6. Quickly place a clean strip of metal into the centre of the petri dish, submerging it below the surface of the agar solution.
7. Place the lid on the petri dish. **Do not move the petri dish until the agar sets.**

$AGNO_3$ CAUSES BURNS AND STAINS SKIN AND CLOTHING.

$PB(NO_3)_2$ IS TOXIC AND IS AN ENVIRONMENTAL HAZARD.

$CUSO_4$ IRRITATES THE SKIN AND EYES AND IS AN ENVIRONMENTAL HAZARD.

$SNCL_2$ CAN IRRITATE THE SKIN AND EYES.

WEAR SAFETY GLASSES, GLOVES AND A LABORATORY COAT.

DISPOSE OF WASTES APPROPRIATELY.

continues ▶

8 Observe the formation of metal crystals over the next 1–2 days. Record whether a reaction occurred.

9 Share your results with the class and record their results.

Questions

1 In one sentence, describe each chemical reaction taking place in the petri dishes.

2 Propose why the crystals were grown in agar rather than in the ionic solution.

3 Explain any colour changes observed.

4 a Write a word equation for each displacement reaction that occurred.

b Write a chemical equation for each of the word equations written in part **a**.

5 Evaluate your prediction from step 2 of the method.

6 Identify any unexpected results when compared to the activity series of metals. Propose reasons for why your results may not align with the expected outcome.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Table 16.5A: Results

Metal strip	Ionic solution in agar	Reaction/ No reaction

Investigation 6.5B

45 min

Precipitation reactions

Process: Questioning and predicting

Focus: Making predictions based on scientific knowledge

In order to formulate a testable hypothesis, you must first identify your independent, dependent and controlled variables. The independent variable is what you purposefully change in an investigation. The dependent variable is what you measure. The controlled variables are all the things you need to keep the same throughout the investigation. To formulate your hypothesis, use the following sentence stem:

It can be hypothesised that if *(something to do with your independent variable)*, then *(something to do with your dependent variable)*, because *(reference to scientific concepts)*.

Hint 1: *More information about questioning and predicting is available in the Science how-to section on pages 401–4.*

Hint 2: *In your conclusion, state whether your hypothesis was supported (correct) or rejected (incorrect).*

Aim

To find out which reactions form a precipitate

Materials

- safety glasses
- nitrile gloves
- spotting tile
- piece of blank paper
- 0.1 mol L^{-1} solutions in dropper bottles of sodium sulfate, sodium carbonate, sodium chloride, potassium iodide, silver nitrate, barium chloride, copper sulfate and sodium hydroxide
- 5 mL of lead nitrate
- paper towel

CHEMICALS MAY ENTER YOUR EYES. WEAR SAFETY GLASSES TO PROTECT YOUR EYES

SILVER SALTS ARE TOXIC AND MAY STAIN YOUR SKIN AND CLOTHES. WEAR GLOVES TO PROTECT YOUR SKIN.

DISPOSE OF WASTE APPROPRIATELY. (COPPER AND LEAD MUST NOT GO DOWN THE SINK.)

Method

1. Copy the results table into your notebook, adding a title.
2. Put the spotting tile on the piece of blank paper. Write the names of the solutions being used down the left-hand side and across the top of the spotting tile, in the same order as your results table. Depending on the size of your spotting tile, you may have to wash it and re-use it to get through all the solutions.
3. Into each cavity on the spotting tile, add one drop of the solution written at the top of the column and one drop of the solution written to the left of the row. Observe whether a precipitate forms. Record your results in the table, by using ‘s’ for soluble and ‘p’ for precipitate. Be careful not to cross-contaminate the solutions.

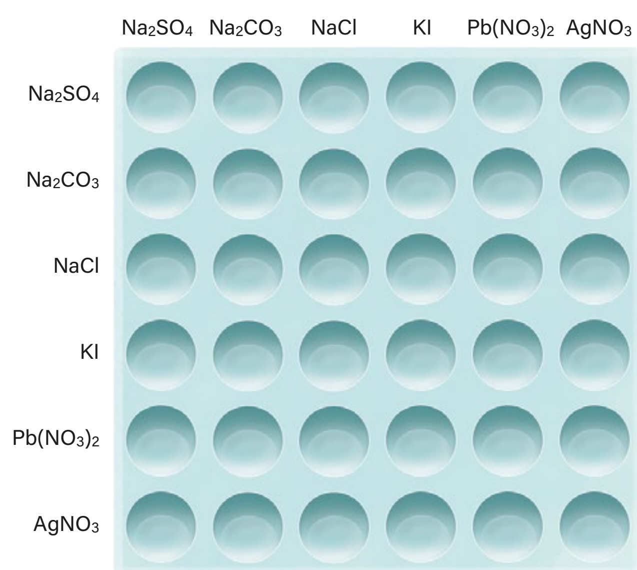


Figure I6.5B: Spotting tile

continues ▶

Questions

1 Propose why you used:

  a dropper bottles of solution instead of solutions from a beaker.

  b spotting tiles and not test tubes to carry out these reactions.

2 Construct a scientific question that would have been suitable for this investigation.

3 **a** Write the net ionic equation for the formation of the silver chloride precipitate.

  b Write net ionic equations for three more reactions of your choice that formed precipitates.

4 **a** Use your results to predict whether the following salts will be soluble: barium sulfate, silver hydroxide, copper carbonate, silver chloride, lead iodide.

  b Evaluate your predictions using the solubility rules.

5 Explain how precipitation reactions occur.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table 16.5B: Results

	Na_2SO_4	Na_2CO_3	KI	$Pb(NO_3)_2$	$AgNO_3$	$BaCl_2$	$CuSO_4$	NaOH
Na_2SO_4								
Na_2CO_3								
KI								
$Pb(No_3)_2$								
$AgNO_3$								
$BaCl_2$								
$CuSO_4$								
NaOH								

Investigation 6.6A

30 min

Cleaning coins

Process: Conducting investigations

Focus: Implementing safe practices

Brainstorm with a partner to identify three possible hazards or risks related to the equipment required for this investigation. Describe specific practices you could implement to increase safety and minimise the risk associated with the required equipment.

Hint: *More information about conducting investigations is available in the Science how-to section on pages 408–11.*

Aim

To investigate the actions of acids and bases

Materials

- safety glasses
- nitrile gloves
- 3 × 50 mL beakers
- 3 coins of the same size and type
- 20 mL of 1 mol L^{-1} hydrochloric acid
- 20 mL ammonia
- 20 mL tap water
- cling film
- 3 × 25 mL measuring cylinders
- masking tape
- marker

Method

1. Copy the results table into your notebook, adding a title.
2. Label the three beakers ‘Hydrochloric acid’, ‘Ammonia’ and ‘Water’.
3. Add a coin to each 50 mL beaker.
4. Measure 20 mL of hydrochloric acid and add it to the first beaker.
5. Measure 20 mL of ammonia and add it to the second beaker.
6. Measure 20 mL of water and add it to the third beaker.
7. Cover all the beakers with cling film and leave them overnight. Record your observations in the results table.
8. Compare your results with those of other groups.

Questions

1. Identify the controlled variables, independent variable and dependent variable.
2. Propose whether the action of acids and bases with metal is a chemical reaction. Provide a reason.
3. Describe what this experiment tells you about cleaning metals.
4. Predict what would happen to the coins if you left them in the solutions for a month.
5. Explain how the results of this investigation could be used in a wider context.

Conclusion

Copy and complete:

‘The results show that: *(respond to the aim)*.’

Table I6.6A: Results

Substance	Observations
Hydrochloric acid	
Ammonia	
Water	

ACIDS ARE CORROSIVE; WEAR SAFETY GLASSES.

AMMONIA GIVES OFF FUMES; DO NOT INHALE; USE IN A VENTILATED ROOM. DISPOSE OF WASTES APPROPRIATELY.

Investigation 6.6B

Acid or base? The pH of common household substances

Process: Conducting investigations

Focus: Collecting and recording data

In this investigation, it is critical to collect and record your data and observations accurately. Before you start the investigation, think about how you will best match the colours in the experiment to the colour range for the cabbage indicator.

Hint 1: *What are some ways to record the colour of something, besides using your memory alone?*

Hint 2: *More information about conducting investigations is available in the Science how-to section on pages 408–11.*

Aim

To prepare a natural indicator and use it to determine the pH of some household substances to establish whether they are acids or bases

Materials

- safety glasses
- nitrile gloves
- 1 red cabbage leaf
- large beaker
- tap water
- hot plate
- strainer
- 5 mL of 0.1 mol L^{-1} hydrochloric acid
- 5 mL of 0.1 mol L^{-1} sodium hydroxide
- solutions of household products: ammonia, baking soda, conditioner, detergent, lemon juice, oven cleaner, shampoo, lemonade, vinegar
- plastic pipette
- 12 test tubes
- 9 rubber stoppers
- test tube rack
- 3 × 10 mL measuring cylinders
- cutting board
- knife

Method

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Chop the cabbage, put it in the large beaker and add enough water to cover it.
3. Put the beaker on the hot plate and bring it to a boil and then simmer for 5 minutes.
4. Once cooled, strain the cabbage. The resulting solution is a natural indicator.
5. Prepare and label three test tubes by adding 5 mL of hydrochloric acid to the first one, 5 mL of sodium hydroxide to the second one and 5 mL of water to the third one.
6. Add 5 drops of the red cabbage indicator to each test tube and record your results. Identify the colour changes in acid, base and neutral solutions.
7. Use the red cabbage pH colour scale (Figure I6.6B) to determine the pH of each solution and record it.
8. To each of the remaining nine test tubes, add 5 mL of one of the provided household solutions.
9. Add 5 drops of the red cabbage extract to each test tube and seal with a rubber stopper. Shake the test tube and observe the colour. Use Figure 16.6B to determine the pH of each solution and record it.

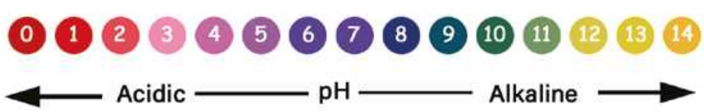


Figure I6.6B: A pH colour chart for red cabbage indicator.

THE HOUSEHOLD SUBSTANCES MAY IRRITATE YOUR SKIN AND EYES AND BE TOXIC. WEAR GLOVES AND SAFETY GLASSES.

USE THE KITCHEN KNIFE WITH CARE.

IF BURNT BY HOT LIQUIDS, RUN COLD WATER ON THE AFFECTED AREASFOR 20 MINUTES.

DISPOSE OF WASTES APPROPRIATELY.

45 min

10 Identify whether each household substance is an acid or a base and record your results in the table.

Questions

1 Propose whether red cabbage is an effective indicator. Explain.

2 Describe any challenges you encountered throughout the investigation.

3 Compare your results to those of three other groups. Discuss the similarities and differences.

4 Propose whether acidic and basic household substances are safe to use in the home. Explain your answer.

Table 16.6B: Results

Substance	Colour with red cabbage indicator	pH	Acid or base?
Hydrochloric acid			
Sodium hydroxide			
Water			

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation **6.7A**

Neutralising hydrochloric acid

Process: Conducting investigations

Focus: Accurately collecting and recording data, information, evidence and findings

In this investigation, you will use qualitative and quantitative observations to explore the features of a neutralisation reaction. You will rely on your ability to observe and record information accurately in order to understand what happens chemically when an acid is neutralised by a base.

Hint 1: Refer to Figure I6.7A to help you identify qualitative observations about neutralising HCl.

Hint 2: Consider why the quantitative information is important in this investigation.

Aim

To neutralise hydrochloric acid using sodium hydroxide (base) and phenolphthalein indicator

Materials

- safety glasses
- laboratory coat
- 50 mL of 0.1 mol L^{-1} HCl
- 50 mL of 0.1 mol L^{-1} NaOH
- 10 mL measuring cylinder
- 3 test tubes
- test tube rack
- disposable pipette dropper
- 3 drops of phenolphthalein indicator
- 50–100 mL beaker

Method

1. Measure 10 mL of 0.1 mol L^{-1} HCl into test tube 1. Add 1 drop of phenolphthalein indicator and swirl it. Record your observations in Table I6.7Aa and set the test tube aside (do not discard it).
2. Measure 10 mL of 0.1 mol L^{-1} NaOH into test tube 2. Add 1 drop of phenolphthalein indicator and swirl it. Record your observations in Table I6.7Aa and set the test tube aside (do not discard it).
3. Carefully add 0.1 mol L^{-1} HCl into test tube 3, counting 1 drop at a time until it is about one-quarter full. Aim for each drop to be consistent in size. Record the number of drops added in Table I6.7Ab.
4. Add 1–2 drops of phenolphthalein indicator to test tube 3 and swirl it.
5. Carefully add 0.1 mol L^{-1} NaOH to test tube 3, counting 1 drop at a time, swirling the test tube in between each drop. You should start to see a pink colour persist when you get close to neutralisation.
6. When the entire solution turns light pink for at least 30 seconds before returning to colourless, this is the point of neutralisation (see Figure I6.7A).
7. Record in Table I6.7Ab the number of drops of NaOH required to neutralise HCl. Share your results with two other groups in the class.
8. Combine the contents of the test tubes from steps 1 and 2 into a small beaker and swirl. Record your observations in Table I6.7Aa.

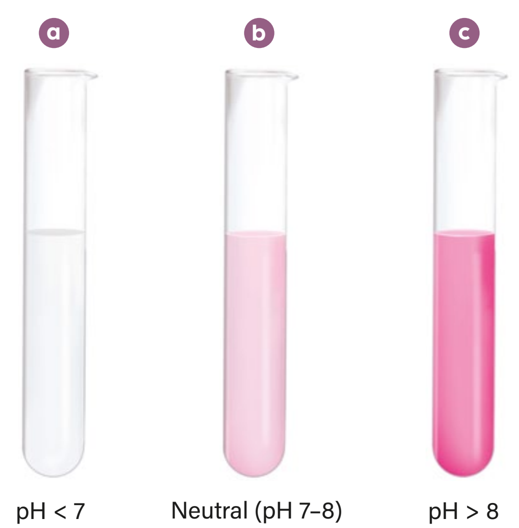


Figure I6.7A: Phenolphthalein indicator is (a) colourless when acidic and (c) bright pink when basic. (b) A neutral solution will have a very faint pink colour.

WEAR A LAB COAT, AND SAFETY GLASSES TO PROTECT YOUR EYES FROM CHEMICALS AND GLASSWARE.

40 min

Questions

1 a Phenolphthalein changes from colourless to pink at about pH 8. Propose why we still assume the solution is neutralised (pH 7) when the colour is faint pink. (Hint: When HCl is neutralised, the pH rapidly changes from 4 to 10 with just 1 drop of NaOH.)

b When no colour is observed in solution, propose why it is better to call it 'colourless' rather than 'clear'.

2 a Identify the cation provided by the base.

b Identify the anion provided by the acid.

c Write the name and chemical formula of the ionic salt that forms in this reaction.

3 a Represent hydrochloric acid being neutralised by sodium hydroxide using a:

i word equation.

ii chemical equation.

b Write the general word equation to represent when an acid is neutralised by a base.

4 a Identify how well you were able to neutralise the HCl by the dropwise method, with reference to results (Table I6.7Ab, 'Final colour of solution').

b Describe how you could improve the accuracy of the results.

5 Did you expect your observations for step 8? Explain with reference to:

a your data from steps 3 and 7.

b the accuracy and precision of measurements in steps 1 and 2.

6 Given that the concentrations of the HCl and NaOH are the same for this investigation, comment on the relative strength of the HCl and NaOH. Justify your response with reference to your results.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table I6.7Aa: Results

Method	Colour of solution	Acidity (acidic, neutral, basic)
Step 1		
Step 2		
Step 8		

Table I6.7Ab: Results

	Number of drops of HCl	Number of drops of NaOH	Final colour of solution	Acidity of final solution (acidic, neutral or basic)
Your group's results				
Group 1 results				
Group 2 results				

Investigation 6.7B

The effects of indicators on acids and bases

Process: Conducting investigations

Focus: Using scientific equipment to conduct investigations and to gather first-hand data and information

In this investigation, you will explore a variety of indicators to see how each of them behaves in the presence of acids and bases. You should gather your observations in a way that helps you to meet the aim of the investigation and organise them effectively so you can use the information to establish a finding.

Hint 1: *How can each indicator be used for a specific purpose?*

Hint 2: *Imagine your results table will be used to construct an indicator chart.*

Aim

To observe the effects of indicators on acids and bases

Materials

- safety glasses
- nitrile gloves
- 25 mL vinegar
- 25 mL of 0.1 mol L^{-1} hydrochloric acid
- 25 mL of 1 mol L^{-1} ammonia
- 25 mL of 0.1 mol L^{-1} sodium hydroxide
- 4 × 10 mL measuring cylinders
- 4 test tubes
- test tube rack
- dropper bottle of universal indicator solution
- universal indicator chart
- bromothymol blue
- methyl orange
- 3 × plastic pipettes
- phenolphthalein
- litmus paper

Method

1. Copy the results table into your notebook, adding a title.
2. Add 5 mL of vinegar, hydrochloric acid, ammonia and sodium hydroxide to each of four test tubes.
3. Add 3 drops of universal indicator to each solution. Use the universal indicator chart to identify each solution as an acid or a base.
4. Remove solutions from test tubes and rinse with water. Refill test tubes with each of the four solutions.
5. Repeat the experiment with the rest of the indicator solutions – bromothymol blue, methyl orange, phenolphthalein, litmus paper (add a small piece of litmus paper to each test tube) – and observe their colours in acidic and in basic solutions.
6. Compare your results with those of other groups.

WEAR SAFETY GLASSES TO PROTECT YOUR EYES FROM CHEMICALS.

Table I6.7B: Results

Substance	**Acid or base according to indicator**				
	Universal indicator	**Bromothymol blue**	**Methyl orange**	**Phenolphthalein**	**Litmus paper**
Vinegar					
Hydrochloric acid					
Ammonia					
Sodium hydroxide					

45 min

Questions

1. Identify the substances that are acidic and those that are basic.
2. If lemonade is acidic, propose what colour it would change bromothymol blue to. Provide a reason.
3. Propose the characteristics of indicators that make them useful.
4. Propose whether we would be able to use bromothymol blue to identify whether two unknown substances were acids or bases. Explain your answer.
5. Describe the limitations of using litmus paper as an indicator.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation 6.7C

Reactions of acids with metals

Process: Conducting investigations

Focus: Collecting and recording data

In this investigation, it is critical to collect and record your data and observations accurately. Before you start the investigation, consider the measuring increments of the thermometer and practise interpreting the measurement of the room temperature. Consider how you will determine the change in temperature.

Hint 1: *Consider how many decimals can be read and recorded from the thermometer you are using.*

Hint 2: *More information about conducting investigations is available in the Science how-to section on pages 408–11.*

Aim

To investigate the rate of reaction of hydrochloric acid with a range of metals

Materials

- safety glasses
- nitrile gloves
- similar-sized pieces of metals: aluminium, copper, iron, magnesium and zinc
- sandpaper
- 50 mL of 2 mol L^{-1} hydrochloric acid
- 10 mL measuring cylinder
- 5 test tubes
- test tube rack
- thermometer
- 5 rubber stoppers
- matches

Method

1. Copy the results table into your notebook, adding a title.
2. Clean all the metals with sandpaper.
3. Add 5 mL of hydrochloric acid to each of the five test tubes.
4. Record the initial temperature of the acid in each test tube.
5. Add aluminium to one test tube and stopper it with a rubber stopper until the reaction stops.
6. Light a match, remove the rubber stopper and hold the match inside the test tube. If a pop sound occurs, it means that the gas produced was hydrogen.
7. Measure the final temperature of the contents of the test tube.
8. Repeat steps 5–7 with the rest of the metals.

⚠

ACIDS ARE CORROSIVE. IF YOU BURN YOUR SKIN, RINSE THE AFFECTED AREA UNDER COLD RUNNING WATER FOR 20 MINUTES.

WEAR SAFETY GLASSES TO PROTECT YOUR EYES FROM ACID AND METALS.

WEAR GLOVES.

DISPOSE OF WASTES APPROPRIATELY.

Table 16.7C: Results

Metals	Initial temperature (°C)	Final temperature (°C)	Change in temperature (°C)	Observations
Aluminium				
Copper				
Iron				
Magnesium				
Zinc				

45 min

Questions

1 List the controlled variables, independent variable and dependent variable.

2 What can you conclude about the bubbles produced?

3 Comment on the final temperature readings obtained.

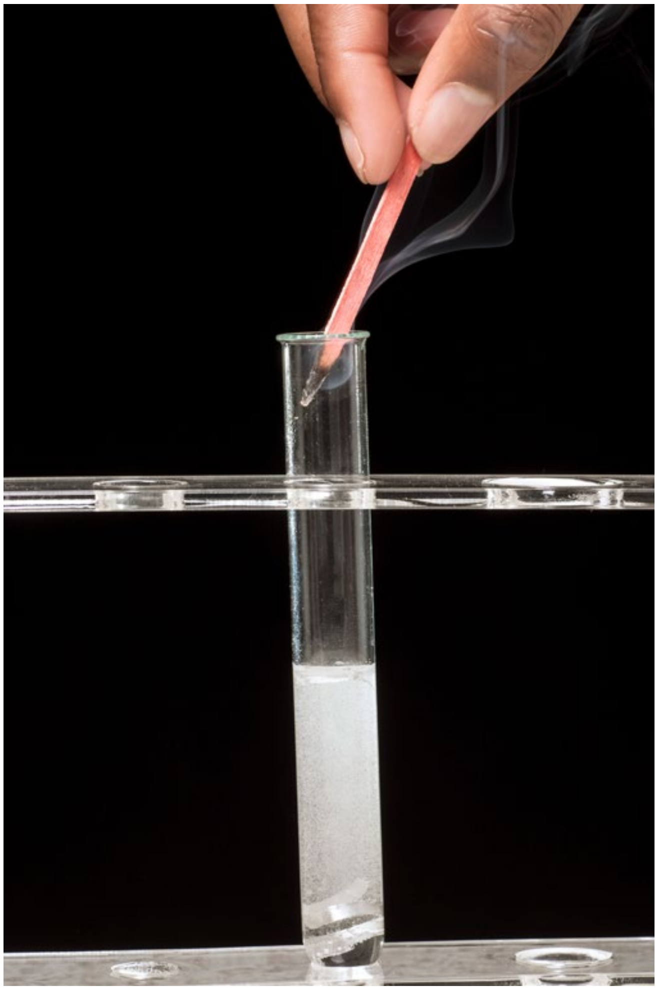
4 a Rank the metals from the most reactive to the least reactive.

  b Explain why you ranked the metals in that way.

5 Did all the reactions give a positive pop test? Explain.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'



Investigation 6.7D

Reactions of acids with carbonates

Process: Conducting investigations

Focus: Accurately collecting and recording data, information, evidence and findings

In this investigation, you will use qualitative observations to predict what happens when an acid reacts with a metal carbonate. You will rely on your ability to observe and record information accurately to understand what happens chemically when an acid reacts with a metal carbonate.

Hint 1: What do most acids have in common? What do metal carbonates have in common?

Hint 2: How can the answer to Hint 1 help you to predict the products of the reaction?

Aim

To observe the reaction between hydrochloric acid and sodium carbonate

Materials

- safety glasses
- 2 test tubes connected by a delivery tube with rubber stoppers
- retort stand
- bosshead and clamp
- 10 mL limewater
- sodium carbonate
- laboratory spatula
- 2 mol L^{-1} hydrochloric acid
- 2 × 10 mL measuring cylinders

Method

1. Copy the results table into your notebook, adding a title.
2. Set up the equipment as shown in Figure I6.7D. Note that the delivery tube must go into the limewater.
3. Add 2 spatulas full of sodium carbonate to the clamped test tube (test tube 1) and have someone hold the test tube containing 10 mL of limewater (test tube 2).
4. Add 5 mL of hydrochloric acid to the test tube containing sodium carbonate and stopper both test tubes. Make sure they are connected by the delivery tube, as shown in the diagram.
5. Observe what happens in both test tubes and record your results.

Table I6.7D: Results

Test tube	Observations	Colour of limewater	Equation
1			Sodium carbonate + hydrochloric acid → ___________
2			

Questions

1. Describe what happened to the test tube containing limewater.
2. An endothermic reaction absorbs heat from the surroundings and the reaction container becomes cold to touch. An exothermic reaction releases heat to the surroundings and the reaction container becomes hot. Do you think this reaction was endothermic or exothermic? Provide a reason to support your response.
3. Based on the reactants, predict the gas that was released during this reaction: oxygen, hydrogen, nitrogen or carbon dioxide? Provide a reason.
4. Complete the sentence:

   When _____________ gas is bubbled through limewater, the limewater turns ___________.
5. Complete the general word equation for the reaction observed in this investigation:

   Acid + carbonate → salt + ________ + water
6. Write a word equation and a chemical equation to represent the reaction observed in this investigation.

⚠

HYDROCHLORIC ACID IS CORROSIVE. WEAR SAFETY GLASSES TO PREVENT IT FROM SPLASHING INTO YOUR EYES.

DISPOSE OF WASTES APPROPRIATELY.

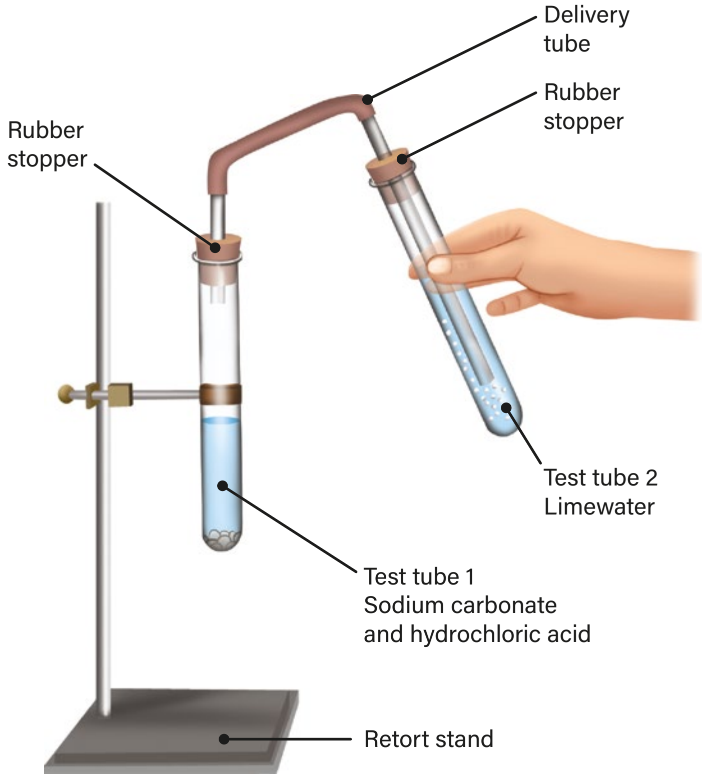


Figure I6.7D: Set-up of the investigation

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Investigation 6.8A

The effect of concentration on the rate of reaction

Process: Questioning and predicting

Focus: Constructing a scientific question

If you know the aim of an investigation, it is possible to construct a scientific question that asks what you are trying to discover. For this investigation, write a scientific question based on the given aim. The question should be detailed enough that the independent and dependent variables of the investigation are clear.

Hint 1: More information about questioning and predicting is available in the Science how-to section on pages 401–4.

Aim

To investigate how concentration affects the rate of chemical reactions

Materials

- safety glasses
- 5 × 100 mL beakers
- black whiteboard marker pen
- 2 × 50 mL measuring cylinders
- 0.15 mol L^{-1} sodium thiosulfate
- 2 mol L^{-1} hydrochloric acid
- 5 × 10 mL measuring cylinder
- stirring rod
- distilled water
- stopwatch
- masking tape

Method

1 Copy the results table into your notebook, adding a title.

2 Label the five beakers 1–5.

3 Mark the bottom of each beaker with an X.

4 Use the two 50 mL measuring cylinders to add sodium thiosulfate and distilled water to the beakers in the volumes indicated in the results table.

5 Add 5 mL of hydrochloric acid solution to each 10 mL measuring cylinder and place them next to each beaker.

6 Carefully add the hydrochloric acid to the sodium thiosulfate solution in Beaker 1. Stir the solution once with a stirring rod and immediately start timing.

7 Stop timing when the black X is no longer visible.

8 Record the reaction time in seconds in the results table.

9 Wash the stirring rod between each use. Repeat steps 6–8 with the remaining beakers.

10 Calculate $\frac{1}{\text{reaction time}}$ for each trial.

SODIUM THIOSULFATE IS HARMFUL IF INGESTED. DO NOT INGEST IT. WASH YOUR HANDS AFTER USING IT.

HYDROCHLORIC ACID IS CORROSIVE TO EYES AND SKIN AND IS AN IRRITANT. IT MAY CAUSE BURNS. IF SPILLED ON SKIN, FLUSH THE AREA WITH COLD TAP WATER. WEAR SAFETY GLASSES.

SULFUR DIOXIDE IRRITATES THE RESPIRATORY SYSTEM. MAKE SURE THE ROOM IS VENTILATED.

Table I6.8A: Results

Beaker	Volume of sodium thiosulfate (mL)	Volume of water (mL)	Volume of sodium thiosulfate (mol L^{-1})	Time (s)	$\frac{1}{\text{time}}$ (s^{-1})
1	50	0	0.150		
2	40	10	0.120		
3	30	20	0.090		
4	20	30	0.060		
5	10	40	0.030		

45 min

Questions

1 List the controlled variables, independent variable and dependent variable.

2 With reference to data, answer the scientific question you constructed before you began the investigation.

3 Use collision theory to justify the finding of the investigation.

4 Should the total volume of each beaker be the same or different? Explain your answer.

5 a Plot concentration vs time, and concentration vs $\frac{1}{\text{time}}$, on separate graphs.

b Compare and contrast each graph, indicating which one 'best' represents the findings.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Investigation 6.8B

45 min

The effect of temperature on the rate of reaction

Process: Questioning and predicting
Focus: Making predictions based on scientific knowledge

To formulate a testable hypothesis, you must first identify your independent, dependent and controlled variables. The independent variable is what you purposefully change in an investigation. The dependent variable is what you measure. The controlled variables are all the things you need to keep the same throughout the investigation. To formulate your hypothesis, use the following sentence stem:
It can be hypothesised that if *(something to do with your independent variable)*, then *(something to do with your dependent variable)*, because *(reference to scientific concepts)*.

Hint 1: *More information about questioning and predicting is available in the Science how-to section on pages 401–4.*

Hint 2: *In your conclusion, state whether your hypothesis was supported (correct) or rejected (incorrect).*

Aim

To investigate the effect of temperature on the rate of a reaction

Materials

- safety glasses
- distilled water at three different temperatures: cold, room temperature and warm (40 °C)
- 3 × 250 mL beakers
- 3 Alka-Seltzer tablets
- stopwatch
- thermometer
- masking tape
- marker

Method

1 Copy the results table into your notebook, adding a title.
2 Measure 200 mL each of warm water, room-temperature water and cold water into three separate labelled beakers.

WEAR SAFETY GLASSES TO PREVENT ANY MATERIAL FROM ENTERING YOUR EYES.

3 Measure the water temperature in each beaker and record it in the results table.
4 Drop an Alka-Seltzer tablet into each beaker. Use the stopwatch to immediately start timing how long it takes for each tablet to dissolve.
5 Stop the timer when the final tablet has dissolved completely.
6 Record the reaction times (in minutes and seconds) in the results table.

Questions

1 Graph the reaction time (seconds) on the *y*-axis against the water temperature (°C) on the *x*-axis.
2 List the controlled variables, independent variable and dependent variable.
3 How does reaction time change with temperature? Do the results support your hypothesis? Why or why not?
4 Use collision theory to justify the finding of the investigation.
5 a If some tablets used are whole and some are broken, propose whether the temperature experiment would still be valid. Explain your answer.
b If some students stirred the water while their tablets were dissolving, propose whether the temperature experiment would still be valid. Explain your answer.
6 If everyone in the class used a different water temperature, propose whether you could average the results. Explain your answer.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table I6.8B: Results

Type of water	Temperature (°C)	Time to dissolve (s)
Cold		
Room temperature		
Warm		

Investigation 6.9A

30 min

The effect of surface area on the rate of reaction

Process: Planning investigations

Focus: Identifying variables

The independent variable is what you purposefully change in an investigation. The dependent variable is what you measure. The controlled variables are all the things you need to keep the same throughout the investigation. Identify the variables for this investigation.

Hint 1: Brainstorm with a partner three things that will be kept the same in your investigation. These are the controlled variables.

Hint 2: More information about planning investigations is available in the Science how-to section on pages 405–8.

Aim

To investigate the effect of increasing the surface area on the rate of a reaction

Materials

- safety glasses
- tap water
- 50 mL measuring cylinder
- 4 × 100 mL beakers
- 4 Alka-Seltzer tablets
- mortar and pestle
- stopwatch
- disposable knife

Method

1. Copy the results table into your notebook, adding a title.
2. Add 50 mL of water to each of the four beakers.
3. Of the four Alka-Seltzer tablets:
   - leave the first one whole
   - cut the second one in half
   - cut the third one into quarters
   - crush the fourth one with the mortar and pestle.
4. Add the whole tablet to the first beaker of water and time how long it takes to dissolve.
5. Add the pieces of the second tablet to the second beaker of water and time how long they take to dissolve.
6. Add the pieces of the third tablet to the third beaker of water and time how long they take to dissolve.
7. Add the crushed tablet to the fourth beaker of water and time how long it takes to dissolve.
8. Make your observations and record your results.

Questions

1. List the controlled variables, independent variable and dependent variable.
2. Do you think your experiment was reliable? Explain your answer.
3. Construct a column graph to show your results. (More information is available about constructing graphs in the Science how-to section on pages 457–61.)
4. Explain what you think the rate of reaction depended on. Justify your response with reference to collision theory.
5. Explain how you changed the surface area of the tablets.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Table I6.9A: Results

Size of Alka-Seltzer tablet	Time taken for the tablet to dissolve (s)
Whole	
Halved	
Quartered	
Crushed	

WEAR SAFETY GLASSES WHILE DOING THIS EXPERIMENT TO PREVENT ANY MATERIALS FROM ENTERING YOUR EYES.

Investigation 6.9B

The effect of a catalyst on the rate of reaction

Process: Planning investigations

Focus: Developing an aim

Every investigation should have a clear aim. What are you trying to accomplish by conducting the investigation? The aim for this investigation is quite broad. After reading the method, rewrite the aim to include more detail to show links between the specific reaction under investigation, scientific theory, and the purpose of this investigation.

Hint 1: *How are the results of this investigation important in a wider context?*

Hint 2: *More information about planning investigations is available in the Science how-to section on pages 405–8.*

Aim

To investigate the effect of a catalyst on a chemical reaction

Materials

- safety glasses
- nitrile gloves
- 50 mL hydrogen peroxide (6% strength)
- tap water
- 50 mL and 100 mL measuring cylinders
- 0.5 g manganese dioxide
- conical flask with a delivery tube attached with a rubber stopper
- retort stand, bosshead and clamp
- trough of water
- electronic balance
- powder funnel
- laboratory spatula

⚠

HYDROGEN PEROXIDE CAN IRRITATE THE SKIN. WEAR GLOVES AND WASH YOUR HANDS IMMEDIATELY IF HYDROGEN PEROXIDE GETS ONTO THEM.

MANGANESE DIOXIDE CAN IRRITATE IF INHALED, SO AVOID SPILLING IT.

DISPOSE OF WASTES APPROPRIATELY.

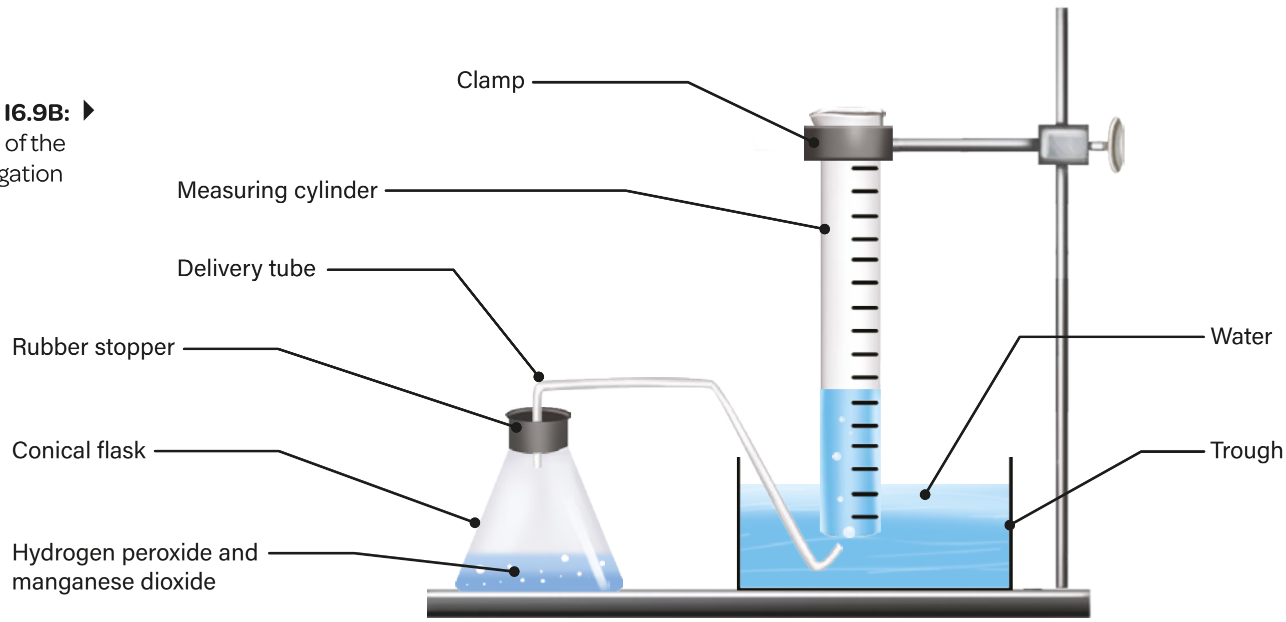


Figure I6.9B: Set-up of the investigation

30 min

Method

1 Copy the results table into your notebook, adding a title.
2 Using a 50 mL measuring cylinder, add 50 mL of hydrogen peroxide solution to a conical flask.
3 Fill the 100 mL measuring cylinder with water, seal the top with your fingers, and invert it into the water trough, as shown in Figure I6.9B.
4 Put the rubber stopper loosely into the conical flask and make sure the delivery tube connects to the inverted measuring cylinder.
5 Measure 0.5 g of the catalyst manganese dioxide.
6 Add the catalyst to the conical flask, put the stopper back into the flask and start the stopwatch.
7 Record the volume of gas given off every 10 seconds. Continue timing until no more oxygen appears to be given off. Record all your observations.

Questions

1 Identify the catalyst in this reaction.
2 Describe how the catalyst affects the rate of decomposition of hydrogen peroxide, with reference to results.
3 Construct a graph to display your results, with time on the *x*-axis and volume of oxygen on the *y*-axis. Be sure to include units.
4 a Identify the trends you see on the graph.
  b Describe the relationship between the independent and dependent variables.
5 Explain the role of the catalyst in this experiment.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table I6.9B: Results

Time (s)	Volume of $O_2(g)$ with catalyst (mL)	Volume of $O_2(g)$ without catalyst (mL)
10		
20		
30		
40		
50		

Investigation 6.9C

Student-designed investigation: investigating rate of reactions

Process: Planning investigations

Focus: Planning an investigation that is reliable and valid

You will work in groups of two or three to produce a plan to investigate how factors affect rates of chemical reaction.

Your student-designed investigation must:

- address a scientific question: What are you trying to find out by conducting the investigation?
- be safe: Identify hazards and describe ways to reduce risk.
- be valid: Variables must be clearly identified and controlled.

Hint 1: Select a chemical reaction to focus your investigation. It might be one that you have already investigated as part of another investigation, or it could be a new reaction, with teacher approval.

*Hint 2: Select **one** factor to explore that affects rate of reactions. All other factors should be controlled.*

Hint 3: Select a dependent variable (e.g. time, mass, volume) and determine a suitable method to measure the dependent variable.

Hint 4: More information about planning investigations is available in the Science how-to section on pages 405–8.

Aim

To produce a plan to investigate a factor that affects the rate of chemical reactions

Materials

(Will vary for each student group)

- safety glasses
- laboratory coat
- assorted substances used in recent experiments:
  - acids and bases: HCl, H_2SO_4, vinegar, NaOH, ammonia
  - metals: copper, magnesium, zinc, aluminium, tin, steel wool
  - carbonates: copper carbonate, sodium carbonate, calcium carbonate
  - catalysts: light source, MnO_2, natural enzymes (e.g. liver, potato)
  - miscellaneous: limewater, sodium thiosulfate, Alka-Seltzer tablets, hydrogen peroxide
- assorted equipment used in recent experiments: measuring cylinder, beaker, test tube and test tube rack, flask, pipette dropper, trough of water, retort stand, bosshead and clamps, stopper with delivery tube, stopwatch, electronic balance, stirring rod, tongs, thermometer, Bunsen burner and heat mat

Method

Part A: Producing a plan for the student-designed investigation

1 Explore the materials provided by your teacher.
  - a Select a chemical reaction to focus your investigation. It might be one that you have already investigated as part of another investigation, or it could be a new reaction.
  - b Select one factor to explore that affects the rate of reaction: concentration, temperature, catalysts, surface area, stirring. All other factors should be controlled.
  - c Select a dependent variable (e.g. mass, volume, time), and determine a suitable method to measure the independent variable. The method might be similar to one you are already familiar with from previous investigations.

2 Propose your idea to your teacher to get preliminary approval. Make adjustments as needed.

3 In your group, write a scientific question for your investigation. (More information about how to write a scientific question is available in the Science how-to section on pages 401–4.)

AN OPEN FLAME IS A HAZARD. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND RUN COLD WATER OVER THE AFFECTED AREA FOR 20 MINUTES. DISPOSE OF WASTES APPROPRIATELY.

45 min
Part A

45 min
Part B

4 Identify the independent variable, dependent variable and controlled variables. (More information about variables is available in the Science how-to section on pages 401–4.)

5 List the materials and equipment required to address your investigation aim.

6 Complete a risk assessment for your investigation: Identify the hazards associated with the required materials. Describe ways to reduce the risks for each of the hazards you have identified. Include disposal of waste (e.g. sodium thiosulfate cannot go down the sink).

7 Write a step-by-step procedure to address the investigation aim, detailed enough for a classmate to follow.

8 Construct a results table. Remember that the independent variable (IV) goes in the left column and the dependent variable (DV) headings go across the top row. Be sure to include units where needed and indicate if multiple trials are required.

9 Get final approval from your teacher.

10 Construct a hypothesis based on scientific knowledge.

Table 16.9Ca: Investigation reaction and variables

Word equation for the reaction under investigation:	**Reactants → Products** →	
Independent variable (what you will change)	**Dependent variable(s) (what you will measure and how)**	**Controlled variables (what you will keep the same and how)**

Table 16.9Cb: Risk assessment

Hazardous substances and equipment	Describe the hazard	Describe ways to reduce risk	Describe what to do if an accident occurs

Table 16.9Cc: Results template

	DV (unit)	DV (unit)	DV (unit)
IV			
IV			

Part B: Carry out the investigation

11 Review your procedure and risk assessment before collecting your materials.

12 Follow your procedure, including safety measures, and record the data in your results table.

13 With support from your teacher, adjust the procedure as needed.

14 Share your results with other groups in the class.

Questions

1 Determine whether the data collected supports or refutes your hypothesis.

2 Justify your findings with reference to collision theory.

3 How well were you able to control the controlled variables? Discuss this in relation to the validity of your results.

4 Describe an extension investigation that could further support your findings.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation 6.10

Modelling the expanding universe

Process: Observing

Focus: Using observations and measurements to answer questions

In this investigation, you will use a model to make observations about the expanding universe to help understand redshift and how scientists measure the speed of expansion and therefore the age of the universe.

Hint: *Review the concept of redshift before completing this activity (see Focus Area 6, page 269).*

Aim

To determine how a galaxy's distance from a reference point affects its speed

Materials

- 1 round balloon
- 5 different coloured stick-on dots
- piece of string approximately 50 cm
- 30 cm ruler
- stopwatch

Method

1 Copy the results table into your notebook, adding a title.

2 Blow up the balloon to about 150 mm and hold the nozzle closed (do not tie it up).

3 Stick the 5 dots (galaxies) onto the balloon (universe). Try to spread them evenly around the balloon.

4 Select one of the dots to be your home galaxy. Use the string to measure the distance between your home galaxy and the other galaxies, as shown in the diagram. Measure the string with the ruler to determine this distance in centimetres.

5 Record these distances in the results table. (Note: The distance from your home galaxy will be 0 cm.)

6 Fully inflate the balloon and use the stopwatch to time how long it takes. Tie the balloon and record the time taken in the results table.

7 Use the string and ruler to again measure the distance from your home galaxy to the other galaxies. Record these distances in the results table.

8 Calculate the change in distance by subtracting the first measurements from the second measurements.

9 Calculate the speed of each galaxy by dividing the change in distance (cm) by the time it took the balloon to inflate (s). (Note: The speed of your home galaxy will be 0 cm s^{-1}.)

10 Plot a line graph with speed (cm s^{-1}) on the *y*-axis and distance (cm) on the *x*-axis.

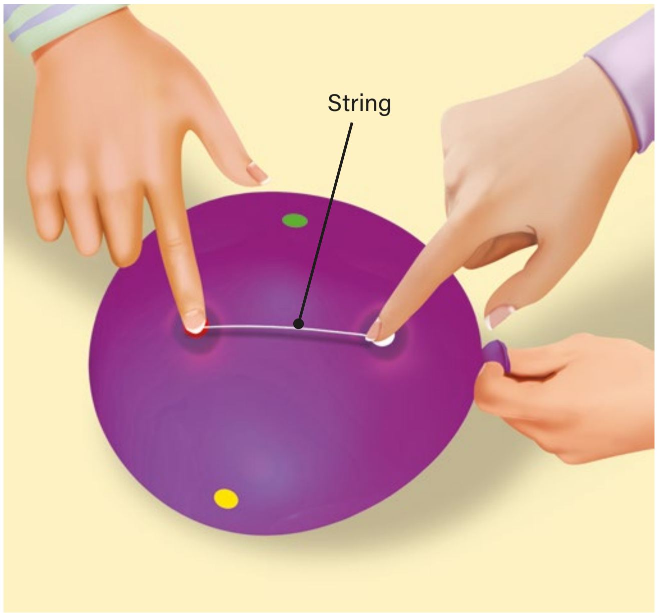


Figure I6.10: Using a piece of string you can measure the distance on the outside of the balloon.

Questions

1 a Explain whether the speeds of all the galaxies are the same.

b If not, describe the relationship between speed and the distance from the home galaxy.

2 Propose what would happen to the results if you had used a different home galaxy.

3 Explain what the results of this investigation tell you about the way the universe is expanding.

40 min

4 Use your observations from this investigation to explain why we observe light from distant galaxies more redshifted than those closer to us.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table 16.10: Results

Colour of dot	Distance from home galaxy (cm)	Distance from home galaxy after inflating (cm)	Change in distance (cm)	Speed $= \frac{\text{distance}}{\text{time}}$ (cm s^{-1})
Red				
Green				
Blue				
White				
Yellow				
Time to fully inflate balloon(s)				

Investigation 6.12

30 min

Half-life coin experiment

Process: Observing

Focus: Using observations and measurements to answer questions

In this investigation, you will use a model to demonstrate the concept of half-life and answer questions about the decay of radioactive substances.

Hint: *Remember the definition of half-life, in relation to how much a sample decays in each half-life period.*

Aim

To model radioactive decay using coins

Materials

- 100 coins
- large container with lid
  (Can also use radioactive decay dice or plastic counters with 2 different sides.)

Method

1. Copy the results table into your notebook, adding a title.
2. Place 100 coins into the container and fasten the lid.
3. Shake the container several times and remove the lid. Carefully empty the coins onto a flat surface, making sure the coins do not roll away.
4. Remove all the coins that show heads.
5. Record the number of coins removed and the number of coins remaining in the results table.
6. Return the remaining coins to the container and repeat steps 3–5 until no coins are left.
7. Draw a graph of your data. Label the *x*-axis 'Shake number' and the *y*-axis 'Number of coins remaining'.

Questions

1. Compare the decay curve of carbon-14 with your graph for the coins. Explain any similarities and differences that you see.
2. Compare your graph to another group's and describe whether it is similar or different. Account for any variations between the graphs.

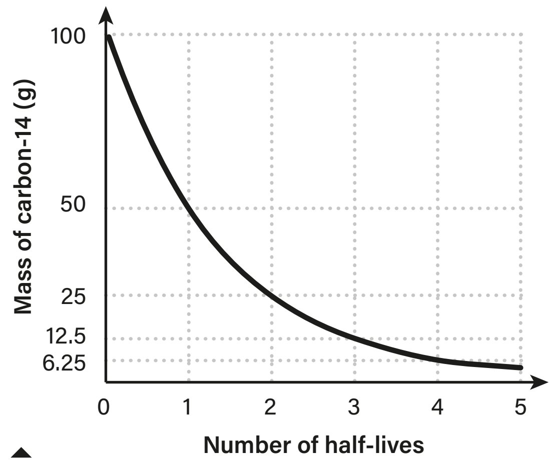


Figure I6.12

3. Recall that the probability of landing heads in a coin toss is ½. Use this information to explain why the remaining number of coins is reduced by about half each time they are shaken and tossed.
4. Propose an alternative way to model the half-life of radioactive decay.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table I6.12: Results

Shake number	Number of coins removed	Number of coins remaining
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

40 min

Nuclear energy debate

Process: Questioning and predicting

Focus: Selecting questions to investigate scientific problems

As a class, you will select and debate a critical question related to the use of nuclear technology and its potential impacts. You will use the information in spread 6.15 and previous sections to help form your arguments and points in the debate.

Hint: Ensure you use scientific evidence to help make your arguments strong and persuasive.

Aim

To debate the issues related to the use, impacts and safety of nuclear technologies

Method

1 Select one of the following scientific problems to debate:

   A The consequences of continuing to rely on fossil fuels are greater than those posed by nuclear energy.

   B It is unethical to cure a patient of an illness by using nuclear technology, as it may have long-term side effects for the patient.

   C Australia is a great place to store nuclear waste for the rest of the world, to help ensure safe and secure nuclear waste storage.

2 Select one of the following methods as the approach to your debate.

Strategy 1: Line debate

1 Divide the class evenly into two groups and form two lines, facing each other.

2 One line is 'for' the issue (the affirmative team); the other line is 'against' the issue (the negative team).

3 Any student from the affirmative team can put forward an argument to begin the debate.

4 If it is judged as a fair point (by your teacher or a student in the adjudicator role), the affirmative team can 'steal' someone from the negative team to join their line.

5 The 'stolen' student now becomes a member of the affirmative team and must put forward an argument for the issue. If it is judged as a fair point, they can again steal someone from the negative team to join their line. If it is not a fair point, any student from the negative team is allowed to put forward an argument and then has the chance to steal an affirmative team member.

6 The debate continues in this way until the teacher calls 'time'. At this point, the line with the most students 'wins' the debate.

Strategy 2: Fishbowl debate

1 Two students sit facing each other in the centre of the room. One student is on the affirmative side and the other is on the negative side of the debate.

2 The rest of the class sits in a circle around them.

3 The two central students begin debating one of the issues, taking it in turns to put forward arguments.

4 Students in the outside circle must listen carefully because they may be called upon to swap with one of the central people at any time in the debate. You could be called upon to join either team, so you need to have arguments prepared for both sides of the issue.

5 Your teacher will nominate students to move from the outer circle into the centre periodically throughout the discussion. The goal is to keep the debate flowing.

Strategy 3: Think–pair–share debate

1 Form a pair and select a topic to 'debate'. Allocate one person as 'affirmative' and one as 'negative'.

2 First, work independently. On your own, think about your response to the issue. Consider it in depth. Write notes if that helps you to organise your thoughts.

3 Now listen respectfully while your partner talks through their arguments for or against the issue, then offer your response. Consider the similarities and differences in your responses.

4 Share your opposing points of view on the issue with another pair or the whole class.

continues ▶

▶ continued

Questions

1 Identify the selected problem that your debate focused on.

2 Reflect on the critical and creative thinking strategy that you used. Explain how the strategy helped you to better understand the issues related to the use of nuclear technology.

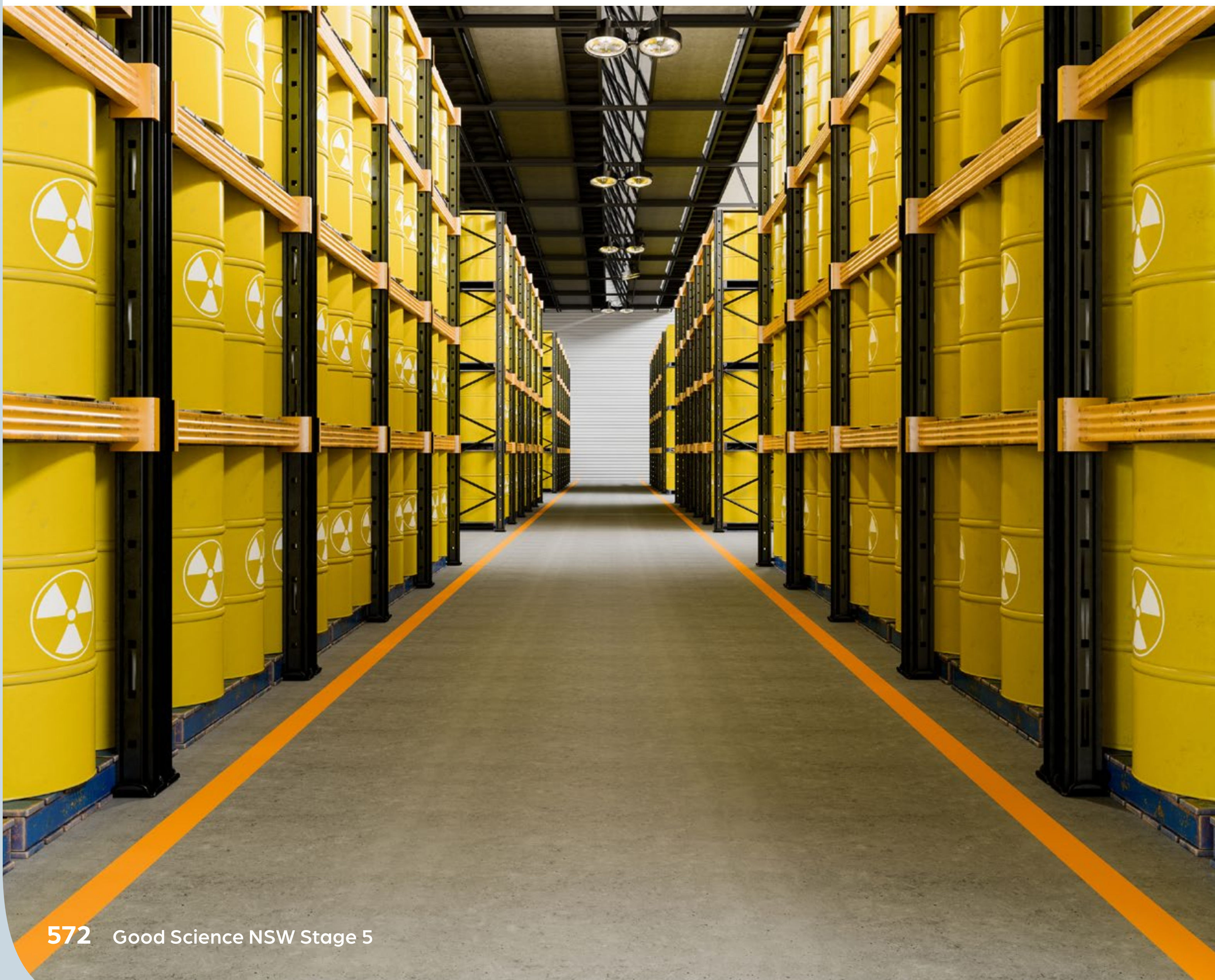
3 Outline three key points from the debate that you think are important.

4 Construct a question related to your selected problem that you could investigate to better understand the issue.

Conclusion

Copy and complete:
'The debate taught me that: *(respond to the aim)*.'

Figure 16.15: Could Australia be a good location for storing nuclear waste for the rest of the world?



Investigation 7.1

30 min

Making a wave machine

Process: Conducting investigations

Focus: Collecting and recording data, information, evidence and findings accurately

In this investigation, you will make a model wave machine to demonstrate how a transverse wave travels. This will show that energy is transferred along the wave, but the matter, or particles, vibrate and return to their resting position.

***Hint 1:** Make sure the wave particles (skewers and jelly babies) are evenly spaced along the model.*

***Hint 2:** You may be asked to help build the wave machine as a class or in larger groups.*

Aim

To model a transverse wave to demonstrate the transfer of energy and features in a wave

Materials

- 4 retort stands, clamps and rods
- gaffer tape or duct tape
- 60–80 wooden skewers
- jelly babies

Method

Part A: Building your model

1 Set up retort stands and rods as in Figure I7.1, at each end of a table or bench approximately 3–4 metres long. Secure the retort stands to the edge of the bench using the G-clamps so that they cannot fall over.

2 On the bench, lay out a long piece of duct tape, sticky side up. The tape must be longer than the distance between the retort stands and rods because you need enough tape to wrap around the rods.

3 Add a jelly baby to each end of a skewer, as shown in Figure I7.1.

4 Take each skewer with jelly babies attached and stick them on to the tape. The skewers should be about 5 cm apart. Keep adding skewers until they cover the entire length of the tape.

5 Stick another layer of duct tape on top of the first piece so that the skewers are between the layers of duct tape. Leave enough tape uncovered at the ends to wrap around the metal rod.

6 Pick up one end of the duct tape and secure it firmly around one of the rods that is being held by the retort stands. Add additional tape if required to ensure it cannot pull off.

7 Pick up the other end of the tape and pull gently until it is fairly tight, and secure it to the other metal rod. You may need to get someone to support the tape along its length while you do this.

8 Ensure that the skewers are horizontal. Adjust any that are not by sliding the jelly babies along the skewers until each one is balanced.

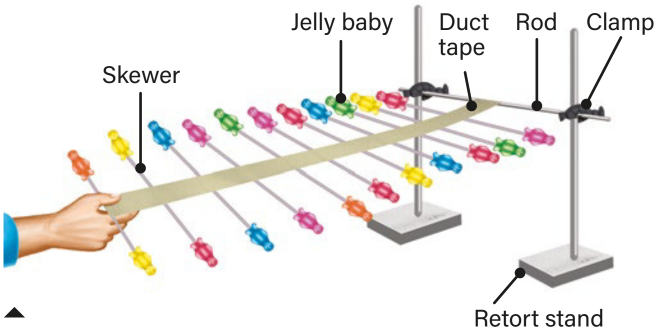


Figure I7.1: Set-up of your experiment

Part B: Testing your model

9 At one end of the model, lift up a jelly baby and let it go – a wave should move down the model and back up once it reaches the other end.

10 Test your model by making:

a larger and smaller waves.

b faster and slower waves.

c lower- and higher-energy waves.

You will need to think about how to make the waves described. As you make each wave, try to estimate whether the wavelength is longer or shorter. Create a table to record your observations in each case and how you made the waves.

continues ▶

Questions

1 What do the jelly babies represent in the model?

2 Using your wave model, describe:

   a how the jelly babies move, including where they are after the wave has stopped.

   b the direction of energy movement.

3 Write a statement that explains how particles and energy move in a transverse wave.

4 The size of the wave, or how far up and down the particles move, is called the amplitude. A larger wave has a higher amplitude. Propose whether a higher-amplitude wave has higher energy. Justify your answer.

5 What evidence can you use from your model to claim that waves only transfer energy and not matter?

Conclusion

Copy and complete:
'The model shows that: *(respond to the aim)*.'

Investigation 7.2

30 min

Waves in a slinky and calculating frequency

Process: Conducting investigations

Focus: Conducting first-hand investigations and accurately recording the collected data and identifying errors

In this investigation, you will investigate transverse and longitudinal waves in a slinky. You will observe the features of these waves, including the amplitude, and measure the frequency of each wave.

Hint 1: *Ensure that the slinky is stretched to the same length in each test.*

Hint 2: *Think about how much energy it takes to make waves of different sizes.*

Aim

To investigate the movement of waves in a slinky and to calculate the frequency of different waves

Materials

- slinky
- masking tape
- metre ruler
- stopwatch

Method

1. Copy the results table into your notebook, adding a title.
2. With a partner, stretch the slinky along the ground and mark the length with masking tape. Make sure the slinky is the same length in the following steps.
3. For each of the following steps **a**–**d**, conduct three trials to get your results, then calculate the average and record your measurements in the results table. When you repeat each step, try to make the waves the same size each time.
   - **a** One person moves their hand to produce small transverse (up and down) waves. Use the stopwatch and count how many waves are produced in 10 seconds. Calculate the frequency in hertz (Hz), by working out how many waves there are in a second and record in your table.

$$\text{Frequency (Hz)} = \frac{\text{number of waves}}{\text{time (s)}}$$

   - **b** Produce large transverse waves. Count how many waves are produced in 10 seconds.
   - **c** Produce small longitudinal (back-and-forth) waves. Count how many waves are produced in 10 seconds.
   - **d** Produce large longitudinal waves. Count how many waves are produced in 10 seconds.

Questions

1. Copy and complete: The two waves investigated are ______________ and ____________________. The _______________ wave produced by the slinky has an up-and-down motion and the ______________________ wave produced by the slinky has a back-and-forth motion.
2. Identify which waves required more energy to create: large or small waves.
3. Describe the relationship between the amount of energy you put in and the amplitude of the waves.
4. Consider the transverse waves you made. Describe whether you can determine any relationship between the frequency of the waves and the amount of energy put in.
5. Describe any challenges you had measuring the frequency that could lead to errors in this investigation. Suggest how those errors could be reduced.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Table 17.2: Results

Wave	Frequency (Hz)							
	Small waves				Large waves			
	Trial 1	Trial 2	Trial 3	Average	Trial 1	Trial 2	Trial 3	Average
Longitudinal								
Transverse								

Investigation 7.4

Investigating amplitude, frequency and pitch of sound waves

TEACHER DEMONSTRATION/CLASS ACTIVITY

Process: Conducting investigations

Focus: Using scientific equipment to conduct investigations and to gather first-hand data and information

In this investigation, you will create and observe a variety of sounds from different objects. You will observe the objects as they vibrate and listen to the sounds created, and use your observations to explain the relationship between the volume, amplitude, frequency, wavelength and pitch.

Hint 1: *Think about how the loudness or volume relates to how much energy is used to create the sound.*

Hint 2: *Consider how a high or low sound relates to the pitch, frequency and wavelength.*

Hint 3: *Try to visualise what the wave would look like in each part of the investigation.*

Aim

To investigate how amplitude and frequency affect the volume and pitch of sound

Materials

- drum (or large tin, rubber skin and rubber bands)
- candle
- matches
- 2 wooden rulers
- 2 G-clamps
- guitar
- tuning forks of different frequency
- xylophone (a toy version will do)
- sound generator and computer or sound analyser app

Method

Part A: Teacher demonstration

1 Make a drum if you do not have one. This can be a large tin open at both ends, with a rubber skin tied over one end and secured with a rubber band.

2 Light the candle.

3 Record your observations of the flame as your teacher points the open end of the drum close to the candle flame and:

   a taps the skin of the drum.

   b taps the drum gently, and then hard.

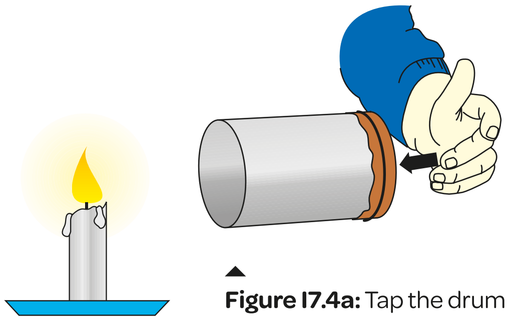


Figure I7.4a: Tap the drum harder and softer and record the effect on the candle flame.

Part B: Student workstations/teacher demonstration

There will be several workstations set up around the room. Visit each workstation and complete the following activities.

1 Wooden rulers:

   a Each wooden ruler is attached to the bench with a G-clamp. One will be sticking out as far as possible from the edge of the bench; the other will stick out only a short distance. Flick each one.

      i Observe the sound created and how fast the ruler seems to vibrate.

      ii Measure how far up and down the ruler moves as it vibrates.

   b Record your observations.

2 Guitar:

   a Pluck the top string, then the bottom string. Record the difference in the sound created.

   Observe each string that was just plucked and record its thickness and tightness/tension.

30 min

b Select and pluck any string. Using the same string, place your finger on a fret and push down to make the string shorter. Observe and record what happens when the string is shorter.

c Pluck a string very gently, and then very hard. Observe and record what happens.

3 Xylophone:

a Tap each metal key, starting with the longer one and moving up to the shorter keys. Observe how the pitch changes as the keys get shorter.

b Record your observations.

4 Tuning forks:

a Each tuning fork will be labelled. Record the frequency of each tuning fork, then tap the fork and describe what happens to the pitch as the frequency gets higher.

b Select a tuning fork and tap it very gently and then harder. Describe and record what happens to the volume/loudness in each case.

Figure I7.4b: Tuning forks of different lengths produce different frequencies.

5 Voice box:

a Touch your voice box gently and make a low sound such as 'aaaaahhhhh'.

Make the same sound in a higher voice.

b Describe and record what you can feel about the vibrations in your voice box in each case.

Part C: Visualising sound waves demonstration/ student activity

Your teacher may set up a sound generator connected to a computer, or you may be asked to download a sound analyser app that can display sound waves. You can use the sound generator, create your own sounds or use some tuning forks for more accurate results.

Create a variety of sounds on the app or computer. You should be able to observe and compare your observations of:

a low- and high-pitched sounds.

b loud and quiet sounds.

Questions

1 a Explain why the flame moves when the drum was tapped in Part A.

b Describe the relationship between the amount of energy in the sound wave and how hard the drum is tapped. Use your observations to justify your answer.

2 a In Part B, describe the relationship between how far each ruler moved up and down, the speed of the vibrations and the pitch of the sound.

b Describe how the speed of vibration relates to the frequency of the sound in each case.

3 a In Part B, you should have observed that a tighter guitar string produced a higher-frequency sound. Explain why this occurred.

b Draw a simple wave diagram to demonstrate and compare the frequency of the wave from the top string to the frequency of the lower string.

c Explain why when you pluck a string harder, it makes a louder sound than when it is plucked gently.

4 For Part B, explain why a shorter key on the xylophone produced a higher frequency than a longer key.

5 a For Part B, describe how the frequency of the tuning fork relates to the pitch.

b Explain how and why hitting the tuning fork harder changes the volume.

c Draw a simple wave diagram to demonstrate and compare the amplitude of the wave from a tuning fork when making a loud and a quiet sound.

6 For Part B, describe how the speed of vibration in your voice box related to the pitch of the sound.

7 For Part C, use your observations of waves from the app or computer to draw the following wave forms.

a A loud sound and a quiet sound.

b A high-pitch/frequency sound and a low-pitch/frequency sound.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation 7.5

20 min

The Doppler effect

Process: Conducting investigations
Focus: Collecting and recording information, evidence and findings accurately

In this investigation, you will explore and observe the Doppler effect, using a moving ball that contains a sound source. As an extension, you can use a sound app to record the Doppler effect and analyse the change in frequency of the waves.

Hint: *If you are unsure about how to explain the increase or decrease in frequency, think about the wavelength and the direction the object is moving.*

Aim

To observe the Doppler effect in action

Materials

- soft foam ball that can be cut open (the Doppler ball)
- craft knife
- 9 V battery
- 9 V buzzer with wires and battery connector
- string
- rubber bands or tape

Method

1. Cut the ball so that the battery and buzzer will fit inside. Ensure it is secured carefully.
2. Attach the battery to the buzzer and turn it on.
3. Insert the buzzer and battery into the ball and secure it with tape or rubber bands so they cannot fall out.

Part A

1. Find a safe space, possibly outside, in a relatively quiet area. Two students stand far apart, and other students sit on the ground between them. The first two students throw the ball quickly to each other, past or over the students in the centre. The students in the centre should listen carefully to the ball as it passes, to hear the change in frequency. Note: The faster the ball moves, the clearer the change in pitch will be.
2. Record your observations.

Part B

1. Tie a 1–2 m piece of string around the ball firmly. Students stand in a large circle. Your teacher stands inside the circle and swings the ball quickly round the circle.
2. Record your observations.

Questions

1. a Describe what happened to the volume of the sound as the ball came closer to you, and then moved further away.
   b Explain why the volume changes when an object is closer or further away.
2. Describe what happened to the pitch, or frequency of the sound as the ball came closer to you, and then moved further away.
3. When the ball was approaching you, explain the changes to the pitch and wavelength, using the wave particle model.
4. Using your scientific knowledge of sound waves, explain the Doppler effect as the ball moved towards and then away from you.
5. Identify at least one piece of evidence from this investigation that supports the theory of the Doppler effect.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Technology activity

If you have a sound analyser app on your smartphone or computer, you can use it to record the sound as the ball or other objects move, and to look at the waveform to observe the frequency changes. For example, you could attach a Bluetooth speaker to a bike and record the sound on a sound analyser app as the bike moves past. Using a sound generator app on the speaker can produce a pure sound, at 1000 Hz, that allows a simpler waveform to be recorded and analysed for this activity. This requires a quieter location for best results.

Investigation 7.9A

30 min

The law of reflection

Process: Conducting investigations

Focus: Using scientific equipment to conduct investigations and to gather first-hand data and information

In this investigation, you will investigate the law of reflection by using a light box to project light rays onto different mirrors.

Hint 1: Draw your scientific diagrams accurately, using a ruler.

Hint 2: Always add the normal to your diagrams to help you measure the angles of reflection and incidence.

Aim

To investigate the law of reflection, using different mirrors

Materials

- plane mirror
- sheet of white paper
- light box and power supply
- concave and convex mirrors
- single-slit and multiple-slit plates for light box
- protractor
- pencil and ruler

Method

Part A: Plane mirror

1 Copy the results table into your notebook, adding a title and rows as needed.

2 Set up your equipment on top of your paper or workbook, using the plane (flat) mirror as shown in Figure I7.9A. Draw a line along the mirror, and then accurately draw the incident and reflected rays of light onto the paper.

3 Remove the light box and draw the normal before measuring the angle of incidence and angle of reflection. Record these angles in your table.

4 Repeat your experiment with at least three different angles of incidence, recording all results in your table.

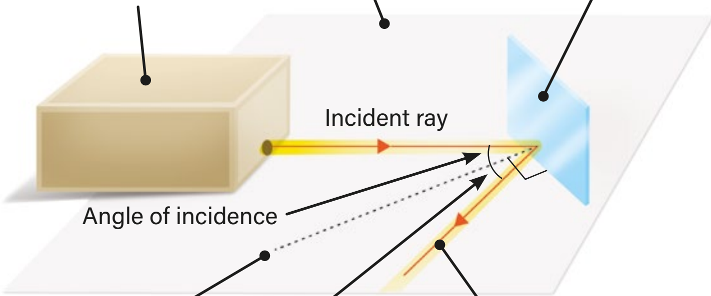


Figure I7.9A: Set-up for the investigation using a plane mirror

THE LENSES, MIRROR AND LIGHTBOX ARE EASILY DAMAGED. TREAT THEM CAREFULLY.

Part B: Curved mirrors

1 Set up the light box on top of another piece of paper or your workbook. Select a multiple-slit plate for the light box to produce several rays at the same time. Place a curved mirror directly in front of the rays, and trace and draw the rays in each case.

2 Observe what happens when you rotate the mirror slightly.

3 Insert a single-slit plate in the light box. Investigate the angle of incidence and angle of reflection by shining the ray at the mirror at different angles. Record your observations.

4 Repeat steps 1–3 with a convex mirror and record your results.

Questions

1 In Part A, did the law of reflection always apply? Justify your answer, using your results.

2 In Part B, did the law of reflection still hold true with curved mirrors? Explain how you tested this.

3 Compare what happens when light reflects from a concave mirror and from a convex mirror.

continues ▶

4 Explain why scientists invented an imaginary line called the normal, and describe how it is useful when investigating light.

5 Summarise the law of reflection.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table 17.9A: Results for Part A

Ray	Angle of incidence (°)	Angle of reflection (°)
1		
2		
3		

Investigation 7.9B

Refraction

40 min

Process: Conducting investigations

Collecting and recording data, information, evidence and findings from investigations accurately

In this investigation, you will investigate refraction by using a light box to project light rays through different-shaped objects, including blocks and lenses.

Aim

To investigate refraction using different lenses and blocks

Materials

- triangular prism
- concave and convex lenses of different thickness
- light box and power supply
- single-slit and multiple-slit plates for light box
- pencil and ruler
- protractor
- sheets of white paper

Method

Part A: Rectangular prism

1 Copy the results table into your notebook, adding a title and rows as needed.

2 Set up your equipment as shown in Figure I7.9B with the prism on an angle and direct a single ray of light to the centre of the prism.

3 Draw, in pencil, around the prism and trace the path of the rays as they are refracted through the prism and out the other side.

4 Remove the prism and draw in the ray under the block between the ray entering and exiting the block. Draw the normal and use the protractor to measure the angle of incidence and angle of refraction for when light enters and exits the block. Record your results in the table.

5 Repeat steps 2–4 using two different angles of incidence and record your results in the table.

Part B: Concave and convex lenses

1 Set up the light box on top of another piece of paper or your workbook. Select a multiple-slit plate for the light box to produce several rays at the same time. Place a convex lens directly in front of the rays, draw around the lens to record the shape, and trace and draw the rays in each case.

2 Repeat step 1 with a thicker convex lens and record your diagram.

3 Repeat steps 1 and 2 with concave lenses and record your results.

Part C: Triangular prism

1 Shine a single light ray at the triangular prism and rotate the prism until you separate the colours of light. Trace the rays and draw a diagram of your results.

2 Turn the prism again and see if you can create an effect called 'total internal reflection', where light reflects off the inside surfaces of the prism and is trapped.

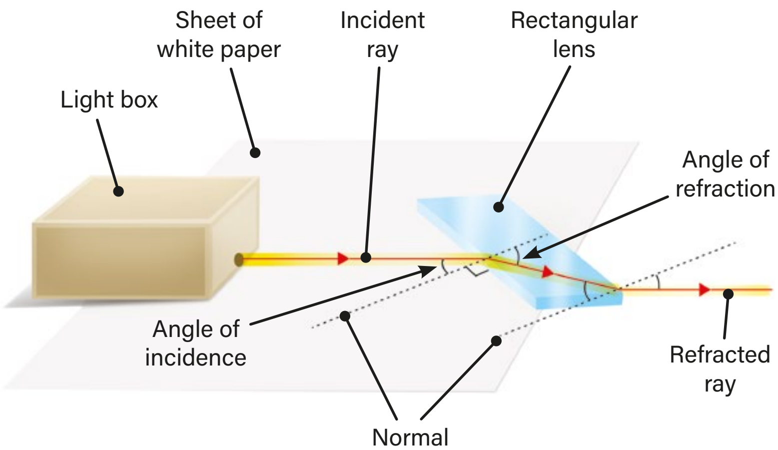


Figure I7.9B: Set-up for the investigation using a rectangular prism

THE LENSES, MIRROR AND LIGHTBOX ARE EASILY DAMAGED. TREAT THEM CAREFULLY.

continues ▶

Questions

1 Compare the direction of the ray before it enters the rectangular prism and after it exits. Is there a difference? Explain why.

2 Using your results from Part A, describe the relationship between the angle of incidence and the angle of reflection when light travels:

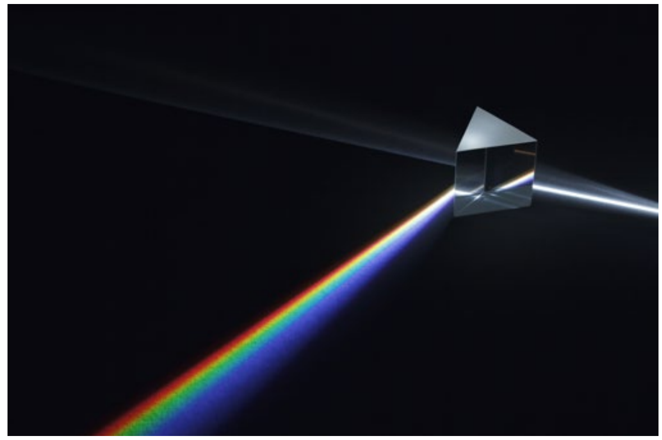
   a from air to glass.

   b from glass to air.

3 Justify your answers in Question 2 in relation to the speed of light as it enters and exits the rectangular prism.

4 Compare what happens when light reflects from a concave lens and from a convex lens.

5 Using your results from the triangular prism, identify the colours in visible light.



Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table 17.9B: Results

Ray	Ray travelling from air to glass		Ray travelling from glass to air	
	Angle of incidence (°)	Angle of reflection (°)	Angle of incidence (°)	Angle of reflection (°)
1				
2				
3				

40 min

Eye dissection

Process: Processing data and information

Focus: Extracting data from a first-hand source

In this investigation, you will dissect a cow's eye to identify and investigate the features and structures of the eye. You will make observations of the eye and record qualitative descriptions and information to help you understand how lenses and the eye work.

If you are unable to complete the dissection for any reason, please discuss it with your teacher. There are virtual dissections available that may be able to be completed as an alternative.

Hint: *Use the diagram of the eye to study the names and functions of each part of the eye and try to locate them on the cow's eye.*

WEAR SAFETY GLASSES AND A LABORATORY COAT, WHICH SHOULD BE WASHED AFTER THIS EXPERIMENT.

WEAR GLOVES AT ALL TIMES AND WASH YOUR HANDS IMMEDIATELY AFTER COMPLETING THIS ACTIVITY.

SCALPELS ARE EXTREMELY SHARP AND SHOULD BE USED WITH CARE. IF YOU CUT YOURSELF, APPLY PRESSURE AND IMMEDIATELY SEEK HELP FROM YOUR TEACHER.

AFTER COMPLETING THIS ACTIVITY, WRAP THE EYE IN NEWSPAPER AND PLACE IT INTO THE PLASTIC BAG PROVIDED.

Aim

To identify the features and parts of the eye and explore their functions

Materials

- safety glasses
- nitrile gloves
- laboratory coat
- cow's eye
- newspaper
- scalpel
- dissecting scissors
- dissection tray
- plastic bag for disposal

Method

1. Ensure you are wearing gloves, your laboratory coat and safety glasses.
2. Place your cow's eye on the newspaper and examine it to locate the following features:
    - cornea – this may look cloudy or blue in colour; it was clear when the cow was alive
    - optic nerve – at the back of the eye
    - sclera – or white of the eye.
3. You are now going to cut the eye open – try not to damage the lens in the front of the eye. The eye is quite tough, and you may need to push harder than you think to cut it. But be careful not to squeeze the eye; otherwise, the fluid inside (the aqueous humour) may squirt out. The goal is to cut around the middle of the eye and separate the back from the front.
4. Once you have cut the eye open, gently separate the parts. Be careful because the fluid may contain the slightly harder lens. Locate the lens and place it on the newspaper. Look through and you should be able to see that it enlarges the letters underneath.
5. Identify the iris, with the hole in the middle (the pupil).
6. Identify the retina in the back half of the eye – it may look shiny. On the retina, try to locate the blind spot – it should be a spot located in front of where the optic nerve is.

continues ▶

Questions

1 Copy and complete the diagram in Figure I7.10, adding labels to identify the parts of the eye.

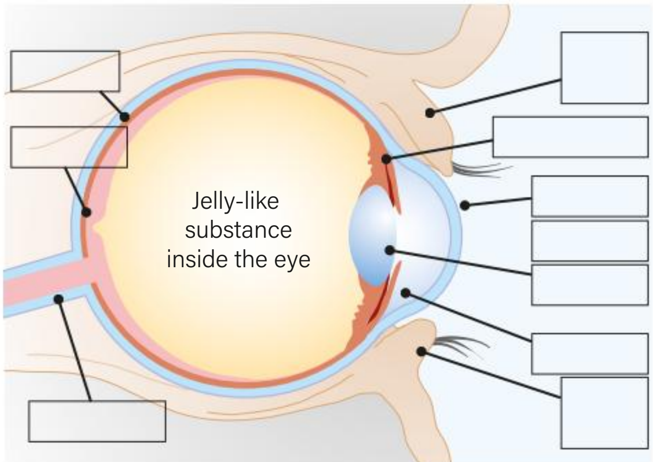


Figure I7.10: Label this diagram of the eye.

2 Explain why the iris has a hole in the centre.

3 Construct a table listing the parts of the eye you identified and their function.

4 Explain whether the eye looked as you expected. What surprised you about the eye's structure during the dissection?

5 Explain how using the eye as a first-hand source of information helped you to understand better how either lenses or the eye work.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation 7.12

60 min

Cars and pedestrians

Process: Conducting investigations

Focus: Conducting first-hand investigations and accurately recording the collected data and identifying errors

In this investigation, you will measure the speed of cars and other vehicles travelling along a road and compare their speeds to the speed limit. You will also measure the speed of pedestrians walking and running. You will calculate speed from the data collected. Make your data as accurate as possible and consider how it could be improved in accuracy.

Hint: As you complete your investigation, think about how you could improve the accuracy of your results, especially regarding how you know when to start and stop the timer.

Aim

To investigate the speed of cars and pedestrians

Materials

- trundle wheel
- coloured markers or cones
- stop watch

Method

Risk assessment

Conduct a risk assessment for this activity.
Consider your chosen location when undertaking your risk assessment – the risk will depend on the road and the conditions you are working under.

Part A: Recording the speed of vehicles

1. Copy the results table for Part A into your notebook, adding a title and rows as needed.
2. Use a trundle wheel to measure 50 m along the footpath beside the road. Place cones or markers at each end of the 50 m distance.
3. Position a student at each end of the 50 m distance.
4. Both students use a stopwatch to time how long it takes a car to travel from the starting cone or marker to the finishing cone or marker. Record this time in the results table.
5. Repeat step 4 so that you have results for 10 cars. If any pedestrians or cyclists travel the length of the 50 m, record their time to compare it later to the cars' speeds.

Part B: Recording the speed of pedestrians

1. Draw up a results table for Part B in your notebook. It will be similar to the one for Part A.
2. Use the trundle wheel to measure 10 m along the footpath beside the road. Place cones or markers at each end of the 10 m distance.
3. Position a student at each end of the 10 m distance.
4. Both students use a stopwatch to time how long it takes for another student to walk the 10 m. Record this time in your results table.
5. Repeat step 4 several times, but record the speed for walking backwards, hopping, running, skateboarding, cycling or an activity of the student's choosing.

WORKING ON THE SIDE OF THE ROAD CAN BE DANGEROUS. DO NOT CARRY OUT ANY ACTIVITIES TO DISTRACT DRIVERS, AND STAY AS FAR BACK FROM THE EDGE OF THE ROAD AS POSSIBLE.

Figure I7.12: Set up your cones 50 m apart.

continues ▶

Questions

1 Outline the formula used to calculate speed, including units for each value.

2 For Part A, compare your results to the speed limit of the road.

3 Which student activity was fastest and which was slowest? How do you know?

4 Identify some of the causes of errors in this investigation.

5 Propose some ways to improve the method and increase the accuracy of the results. Think about how technology could help.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table 17.12: Results for Part A

Distance: 50 m Speed limit of road: ________	Time (s)			Speed	
	Time 1	Time 2	Average	(m s^{-1})	(km h^{-1})
Car 1					
Car 2					
Truck 1					

Investigation 7.13

90 min

Ticker timers

Process: Processing data and information

Focus: Calculating a range of measurements using data and formulas, and using SI units

In this investigation, you will investigate speed and acceleration using a ticker timer. Ticker timers create a motion diagram of dots, in which the spacing of the dots represents speed. After collecting your data, you will draw graphs to analyse and calculate the speed and acceleration.

Aim

To use a ticker timer to analyse and calculate the relationship between speed, distance and acceleration

Introduction

A ticker timer is a device that has a vibrating arm that hits a ring of carbon paper (Figure I7.13a). As a strip of paper (ticker tape) is pulled between the arm and carbon paper by a moving object, the ticker timer leaves dots on the ticker tape. The dots on the tape represent motion of the object, as shown in Figure I7.13b.

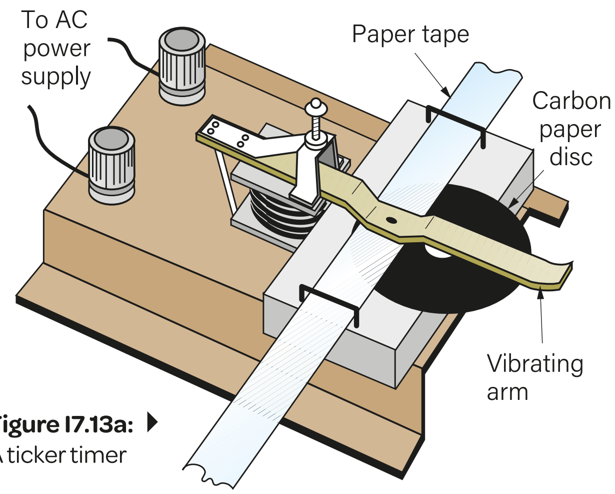
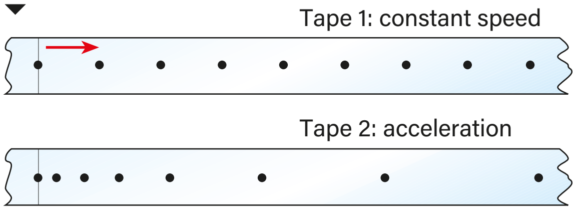


Figure I7.13a: A ticker timer

Figure I7.13b: A ticker timer tape showing motion



Materials

- ticker timer
- ticker tape
- power-pack
- 2 electrical leads
- G-clamp
- dynamics trolley
- sticky tape
- scissors

Method

Part A: Constant speed

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Set up the ticker timer and attach it to the edge of the bench with a G-clamp.
3. Cut off about 1 m of ticker tape and thread it through the ticker timer. Attach one end of the tape to the trolley.
4. Start the ticker timer and pull the trolley and tape through the ticker timer at a constant speed. Label this tape and the direction of motion.
5. Repeat with a new piece of tape at a:
   a. higher constant speed.
   b. lower constant speed.
6. To analyse your tape, draw a line through the first clear dot, and then every fifth dot after that. Every five dots represents a time interval of 0.1 s.
7. Measure the distance to each marked dot (or interval) as shown in Figure I7.13c. Record the distance travelled and total time to each interval in your results table.
8. Draw a distance–time graph of your results. Make sure your line of best fit is straight.
9. Calculate the slope or gradient to find the average speed (your answer will be in cm s^{-1}).
10. Repeat your analysis of the tape for the lower and higher speeds.

continues ▶

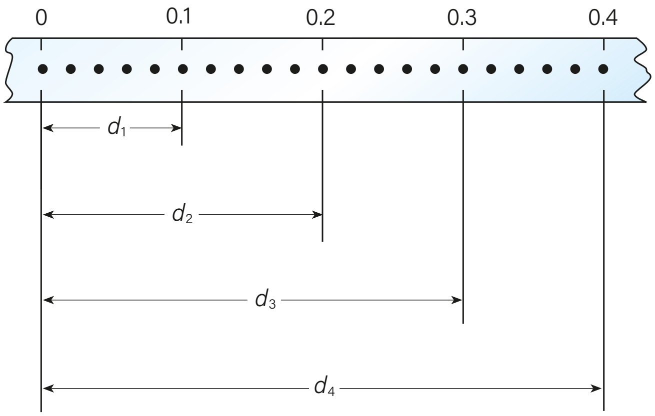


Figure I7.13c: A ticker timer tape analysis

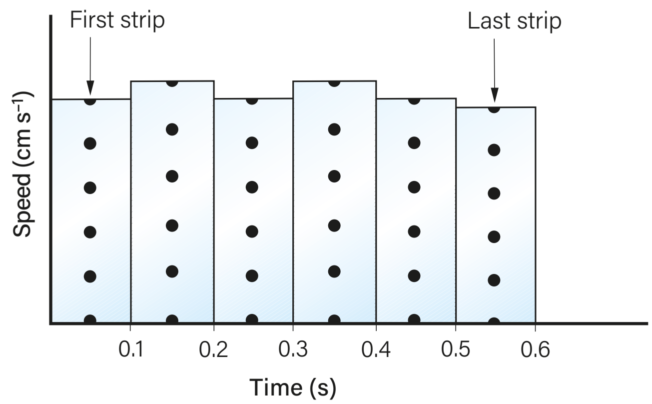


Figure I7.13d: A ticker tape speed–time graph

Part B: Acceleration

1 Repeat the steps in Part A, this time pulling the trolley so that the speed steadily increases. If it helps, tilt the table by placing one end on a block, or place the trolley on a ramp, so that the trolley rolls downhill and steadily accelerates.

2 Analyse the tape and draw a distance–time graph.

Questions

1 Compare the slope of each graph in Part A for constant speed. What do you notice about the relationship between the slope and the speed?

2 Outline the formula used to calculate acceleration, including units for each value.

3 a Explain the shape of the distance–time graph for acceleration in Part B.

  b Describe how this is different from the graphs from Part A of constant speed.

4 Calculate the average acceleration for Part B from your graph.

5 Select one piece of tape for constant speed, and one for acceleration. Cut them up at the 0.1 s marks and number each piece to keep them in order. Stick them on a piece of paper in order, vertically, to create a speed–time graph, as shown in Figure I7.13d. Compare the graphs you have just created for constant speed and acceleration. Explain what you observe.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Table I7.13: Results. You will need a separate results table for each piece of tape.

Tape speed: ________________	
Distance (cm)	**Total time (s)**
1	
2	
3	
4	

Investigation 7.14A

30 min

Car crashes and inertia

Process: Conducting investigations

Focus: Collecting and recording data and evidence from first-hand investigations accurately

In this investigation, you will use a trolley and crash-test dummies to replicate a car crash. You will collect data and evidence to explain the application of and demonstrate your understanding of Newton's laws.

Hint: *Think about each of Newton's laws as you undertake the investigation, where they can be identified in action, and how you can explain them.*

Aim

To investigate and demonstrate Newton's laws by modelling a car crash with crash-test dummies

Materials

- plasticine
- dynamics trolley
- talcum powder
- wooden plank
- textbooks to prop up plank
- brick
- metre ruler

Method

1. Copy the results table into your notebook, adding a title.
2. Make three crash-test dummy models from the plasticine – small, medium and large. These will represent different-sized people. Make sure they are very different sizes, to get better results.
3. Lightly dust the top of the dynamics trolley with talcum powder and sit the smallest dummy on top. The powder is to make sure the crash-test dummy is not stuck down.
4. Set up the ramp and the brick as shown in Figure I7.14A. Place the metre ruler next to the brick so that the 0 cm mark is at the near edge of the brick.
5. Place the trolley with the dummy at the top of the ramp and then release it. The trolley should travel down the ramp and strike the brick at the bottom.
6. Record how far the crash-test dummy travels after striking the brick.
7. Repeat steps 5 and 6 twice to obtain two more results. Calculate the average distance from the three trials.
8. Repeat steps 5–7 for the other two larger crash-test dummy models.

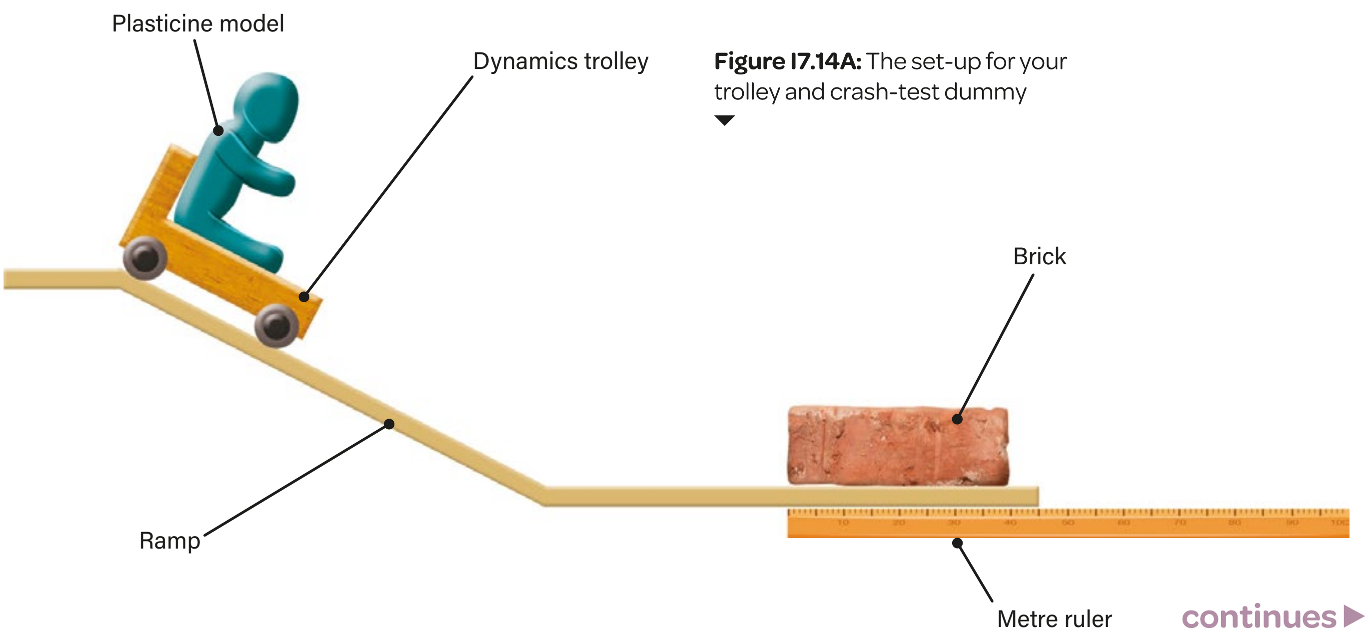


Figure I7.14A: The set-up for your trolley and crash-test dummy

continues ▶

Questions

1 Using your data, explain which crash-test dummy travelled the furthest and the least after striking the brick. Propose reasons for the differences in distance travelled.

2 Explain the term ‘inertia’ and how it relates to this investigation (in particular, the crash-test dummies).

3 Explain how this investigation demonstrates:
   a Newton’s first law.
   b Newton’s second law.
   c Newton’s third law.

4 Using evidence from this investigation, propose reasons for why wearing a seatbelt in a car is important.

Conclusion

Copy and complete:
‘The results show that: *(respond to the aim)*.’

Table 17.14A: Results

Crash-test dummy	Distance (cm)			
	Trial 1	Trial 2	Trial 3	Average
Small				
Medium				
Large				

Investigation 7.14B

20 min

Balloon rockets

Process: Conducting investigations

Focus: Using scientific equipment to gather data

Rockets are a great way to demonstrate Newton's third law. In this investigation, you will observe an action and reaction pair of forces and use your observations to explain and verify Newton's third law.

Hint 1: *Think about how the action and reaction pair provides evidence for the explanation of Newton's third law.*

Hint 2: *Is there any equipment you could use to improve your data collection in this investigation?*

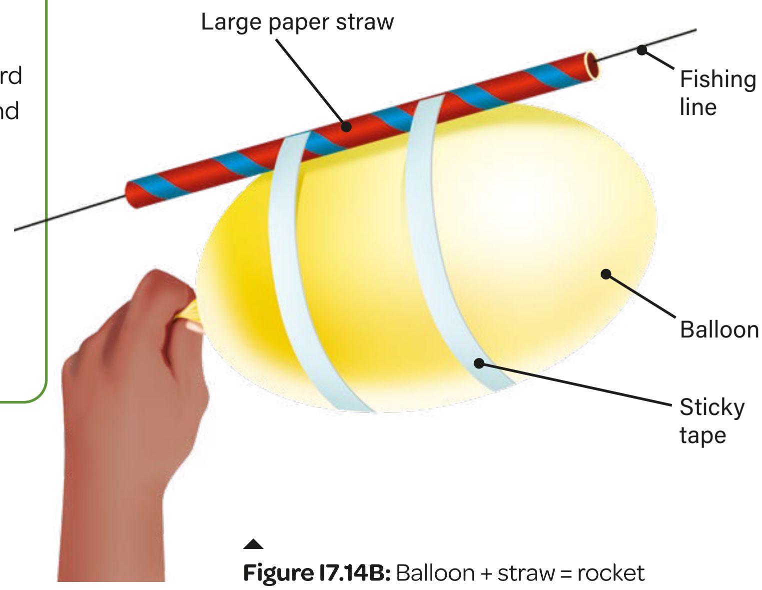


Figure I7.14B: Balloon + straw = rocket

Aim

To demonstrate Newton's third law, using balloon rockets

Materials

- balloon
- large paper straw
- fishing line
- sticky tape

Method

1. Inflate the balloon to about the size of a basketball. Hold the mouth of the balloon closed, but don't tie it off.
2. Attach the straw to the balloon as shown in Figure I7.14B. Thread the fishing line through the straw.
3. Ask another student to hold one end of the fishing line while you hold the other, keeping it tight.
4. Make sure the balloon is near one end of the fishing line so that most of the line is out the front of the balloon rocket.
5. Let go of the mouth of the balloon. Record your observations.

Questions

1. Describe the motion of the balloon and the direction of the air escaping from it.
2. Draw a diagram to show the action and reaction force pairs.
3. Explain how the motion of the balloon demonstrates Newton's third law of motion.
4. Propose how you could modify the set-up to allow the balloon to travel further and faster.
5. If you inflate a balloon and then let it go when it is not attached to a straw or the line, it flies all over the place in an unpredictable path. Explain why this occurs in relation to the force of escaping air.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation 7.15

Acceleration and mass

Conducting investigations

Focus: Conducting first-hand investigations and accurately recording the collected data and identifying errors

In this investigation, you will use a trolley with different masses to investigate Newton's second law. As you complete this investigation, be sure to take steps to accurately make measurements and record data. Think about the accuracy of your data, and how errors may affect your results or conclusions.

Hint: *To calculate the force pulling the trolley, you will need to think about the weight.*

Aim

To investigate the effect of increasing mass on an object's acceleration

Materials

- masking tape
- fishing line
- 100 g mass carrier
- 4 × 100 g masses
- bench-mounted pulley
- dynamics trolley
- mass carrier
- stopwatch

(Optional: This investigation can be expanded to use ticker timers or motion sensors to capture the acceleration.)

Method

1. Copy the results table into your notebook, adding a title.
2. On a desk or benchtop, place two strips of masking tape 1 m apart. These strips represent the start and finish lines. Make sure there is at least a dynamics trolley's length of benchtop before and after each strip of tape.
3. Attach a 100 g mass to one end of the fishing line. Thread the other end over the pulley and attach it to the trolley, as shown in Figure I7.15.
4. Release the mass so that it drops straight down to the ground. Use the stopwatch to time how long the trolley takes to travel from the start line to the finish line. Make sure you catch it before it falls off the table. Perform three trials and record the times in your results table.

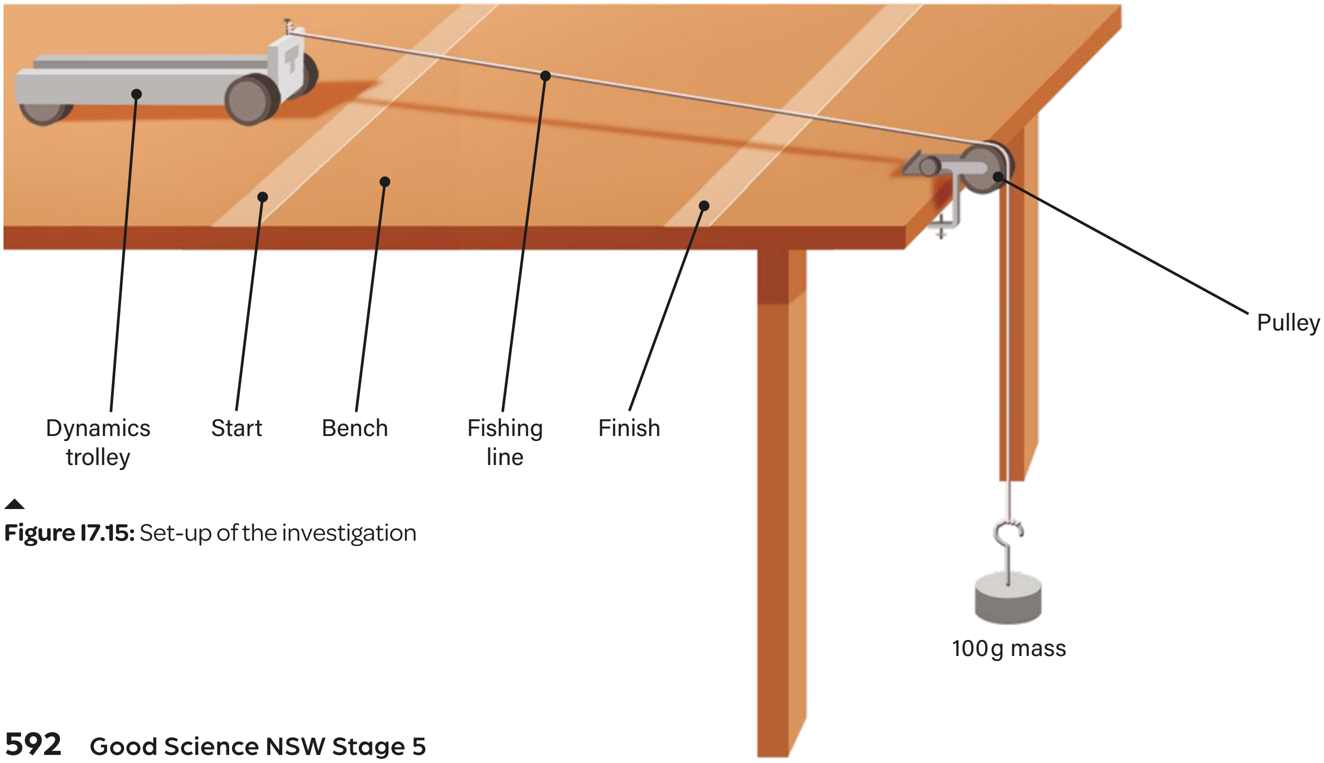


Figure I7.15: Set-up of the investigation

40 min

5 Add a 100 g mass to the trolley and repeat step 4.
6 Repeat step 4 with masses of 300 g, 400 g and 500 g on the trolley. Record all your data.
7 Calculate the average acceleration for each mass in your results table.

Questions

1 What can you infer about the time taken to travel 1 m and the acceleration of the trolley?
2 Describe any pattern you notice in your results.
3 Explain how your results confirm Newton's second law.
4 a Which part of the apparatus provided the force that accelerated the trolley?
  b Calculate the force pulling the trolley.
5 Identify any other forces acting on the trolley and describe the effect they had on it.
6 Identify any sources of error in this experiment and propose improvements to the method that could reduce these.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table 17.15: Results

Mass (g)	Time (s) to travel 1 m			
	Trial 1	Trial 2	Trial 3	Average
100				
200				
300				
400				
500				

Investigation 8.2

45 min

What if Earth stopped rotating for 1 second?

Process: Problem-solving

Focus: Explaining problems using cause-and-effect relationships

When calculations are used to give us data, they can be linked to ideas and investigable problems. How would knowing the speed at which Earth rotates allow us to see the problems that might occur if Earth stopped spinning for 1 second?

Hint 1: *Your movement would not stop if Earth suddenly did – you would keep going!*

Hint 2: *If everything kept going, what would that mean for the life and objects on Earth?*

Aim

To calculate the speed of the rotation of Earth

Materials

- calculator
- provided data:
  - diameter of the Earth 12 742 km
  - 1 day = 24 hours (see 'Scientific numeracy' in the Science how-to, page 448, to help with the conversions required in the method)
  - formula for the circumference of a circle:

$$C = \pi d$$

where d is the diameter

  - formula for speed (velocity):

$$v = \frac{d}{t}$$

where v is velocity, d is distance, t is time

  - formula for distance travelled:

$$d = v \times t$$

Method

1. Use the information provided to calculate the:
   a. number of seconds in a day.
   b. circumference of Earth, and convert the distance in km to metres.
2. Divide the circumference of Earth in metres by the number of seconds in a day to find the speed of rotation of Earth in m s^{-1}.

Questions

1. Identify how fast Earth is spinning.
2. If Earth stops rotating, you keep going at the same speed. Calculate how far you would travel in 1 second.
3. Buildings designed for cyclone areas can withstand winds of up to 240 km h^{-1}. Describe the impact on these buildings.
4. If Earth stopped rotating for 1 second, describe what would happen to people:
   a. on a cruise ship.
   b. in an aeroplane.
5. Explain the link between Earth's rotation and our survival.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Investigation 8.3

45 min

Do red cars go faster?

Process: Problem-solving

Focus: Evaluating scientific claims

The claim that red cars go faster will be supported by some evidence and the challenge is to determine if this evidence is valid and reliable. If not, counterevidence needs to be provided.

Hint: *What factors are considered when classifying a claim as valid and reliable?*

Aim

To prove or disprove the claim that red cars go faster

Evidence: An internet search uncovers the following evidence

- The majority of sports cars are red. Ferrari cars, considered to be elite sports cars, are nearly all red. There is no doubt that Ferrari cars are fast.
- There is a physics phenomenon called redshift (see Focus Area 6, page 269). Red light travels faster, so the car can slipstream in it, making it faster.
- When sunlight (white light is mixture of all colours) shines on a red car, we see red because the car is absorbing all the colours except red. It is reflecting the red wavelength, which is the longest. Wavelengths and frequency are inversely proportional. So, a wave of longer wavelength has a lower frequency than a wave with a shorter wavelength. The red car just absorbed most of the higher frequencies, giving it extra energy, $E = hf$. Energy is proportional to frequency. The higher the absorption of frequency, the more energy your car absorbs and the faster it goes. This is the scientific reasoning for why a red car is faster.
- An anonymous person online says, 'We've had a lot of red cars in to test lately. Coincidentally, the red ones tend to be the quick ones.'
- On a website created by an unknown person, the claim is made that the colour red promotes adrenaline release and feelings of excitement or intensity, which can certainly give the *appearance* that a red object is moving faster, as well as possibly encourage the drivers of red vehicles to drive faster. Additionally, in fiction, red tends to be associated with elements/powers such as fire and lightning.
- Figure 18.3 is an image of white light being split into its component colours. Red light travels a much shorter distance than all the other colours and so must be faster.

Questions

1 Read the evidence and describe the sources that each of them may have come from.

2 Outline reasons why each statement is correct or incorrect.

3 Comment on the counterclaim that colour does not affect the speed of a car. Can you find any evidence to justify this claim?

4 Using the information you have collected, evaluate the claim that 'red cars travel faster'.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

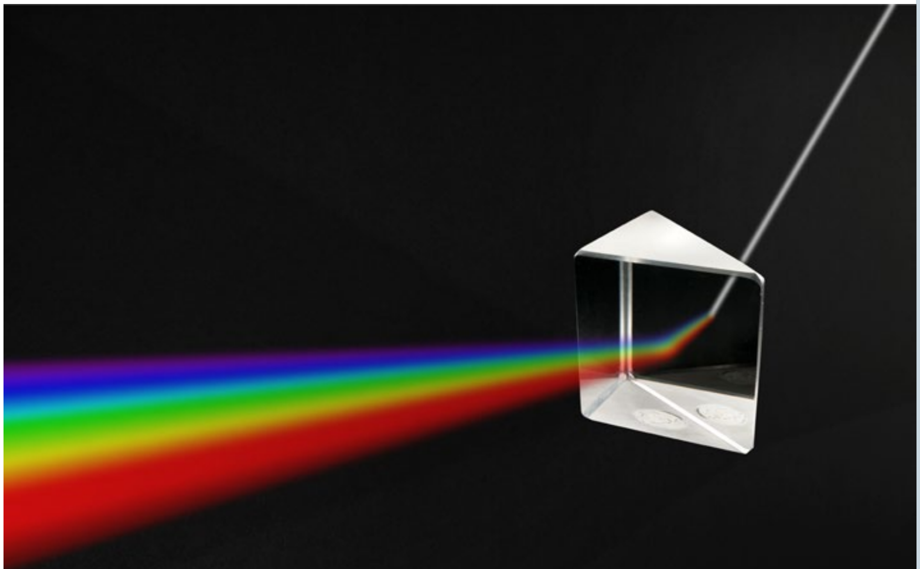


Figure 18.3: White light being split into colours

Investigation 8.4

15 min

After 24 hours, repeat step 4

Sugary drinks and teeth

Process: Problem-solving

Focus: Proposing solutions to problems

A common claim that is made in the media is that sugary drinks are bad for your teeth. Use this investigation to collect data that will put that claim to the test.

Hint: *How will your data allow you to make a conclusion relating to this drinks-based problem?*

Aim

To determine the effect of sugary drinks on the surface of teeth

Materials

- 6 eggs and the following drinks: cola, cordial, fruit juice, 2 non-cola sugary soft drinks, tap water
- 250 mL beakers or containers to hold the liquid

Method

1. Copy the results table, adding a title.
2. Label each beaker or container with the name of one of the drinks. Place an egg in each beaker.
3. Pour each drink into a beaker so that each egg is completely covered. Put water into the sixth beaker to use as the experimental control.
4. After 30 minutes examine each egg, take a photo, and write a description of any effect.
5. After 24 hours, repeat step 4.

Questions

1. Identify the drink that had the greatest effect on the egg after:
   a. 30 minutes.
   b. 24 hours.
2. Explain the purpose of having one egg in water.
3. Propose changes you could make to the investigation to determine the effect of acidity in drinks on teeth.
4. Some suggestions to reduce the effect of sugary and acidic drinks include using a straw, rinsing your mouth with water, avoiding these drinks before bed, and not brushing your teeth within an hour of consuming a sugary acidic drink. Explain how each of these methods could help to protect your teeth.
5. This experiment focused on one aspect of sugary drinks and teeth. Propose three other investigations you could design and conduct to determine the impact of different measures on reducing the negative impacts of sugary drinks on teeth.

Table 18.4: Results

Type of drink	Condition of egg after	
	30 minutes	24 hours
Cola		
Cordial		
Fruit juice		
Non-cola sugary soft drink 1		
Non-cola sugary soft drink 2		
Tap water		

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Investigation 8.5

30 min

Where did Earth's water come from?

Figure 18.5: Earth is mostly water.

> **Process: Communicating**
> **Focus: Presenting scientific findings**
> Sometimes scientists need to present their findings as evidence-based arguments; this shows the audience that available evidence has been considered.
> ***Hint:*** *More information is available about scientific arguments in the Science how-to section on* *pages 444–45.*

Aim

To construct a scientific argument that answers the question of the origin of water on Earth

Materials

- device with internet access

Background information

Earth is about 70% water. Water is not created or destroyed, so the total amount of water on Earth is constant unless a significant event, such as the collision that resulted in the formation of the Moon, alters the amount of water. There are two main theories about the origins of Earth's water.

- Earth held onto water when it formed 4.5 billion years ago and the water remaining on Earth was recycled through the mantle.
- Most of Earth's water was evaporated when it formed, and even more was vaporised when the Moon was formed. So, Earth's water is a result of ice-rich asteroids hitting our planet.

Method

1. Search the internet and find some reliable sources supporting each theory.
2. Use secondary research to find and record information about how using isotopes of hydrogen helps us to understand where Earth's water came from.
3. Use secondary research to find and record how opals, and their locations, may help us to understand where Earth's water came from.
4. The planets nearest Earth are rocky, with little or no water. Describe the influence this may have when choosing a theory.

Questions

1. Compare the two theories of the origin of water on Earth and conduct further research. Which theory has the most support from your research? Explain.
2. Discuss whether the two main theories are mutually exclusive.
3. Discuss if your research indicated that both theories could be true or not.
4. Construct a presentation that would allow you to put forward an argument about where the water on Earth came from, based on the evidence you have collected.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Investigation 8.6

45 min

The influence of advertising

Process: Analysing data and information

Focus: Assessing information for accuracy, reliability and validity

There is a lot of correct and informative information on the internet. However, there is also a lot of information and advice that has no scientific basis. How can you determine if the information relating to a claim is scientific or pseudoscience?

Hint 1: *Refer to spreads 8.2–8.5 for information on scientific claims.*

Hint 2: *What factors determine the accuracy, reliability and validity of secondary-sourced data?*

Aim

To use secondary sources to determine the accuracy of a claim

Materials

- device with internet access

Background information

Select one of the pseudosciences discussed in spread 8.6 or a topic of your choosing. Investigate the claim and examine the evidence, if there is any, that supports the claim. Then provide evidence that disproves the claim, making it a pseudoscience.

Method

1. Choose a claim you want to research. Some examples include hair regrowth, fad diets and get-rich-quick schemes.
2. Search for information on your chosen claim.
3. Record three sites that provide you with information on this claim.

Questions

1. Identify the claim you are investigating.
2. Give three pieces of evidence from different online sources that support the claim.
3. Provide three pieces of evidence that show the data is inaccurate, unreliable and invalid.
4. Assess each source for its accuracy, reliability and validity.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Figure I8.6: Some advertisements claim that their hair cream products can cause hair to regrow on a person's head!

Investigation 8.7

45 min

Earth is flat!

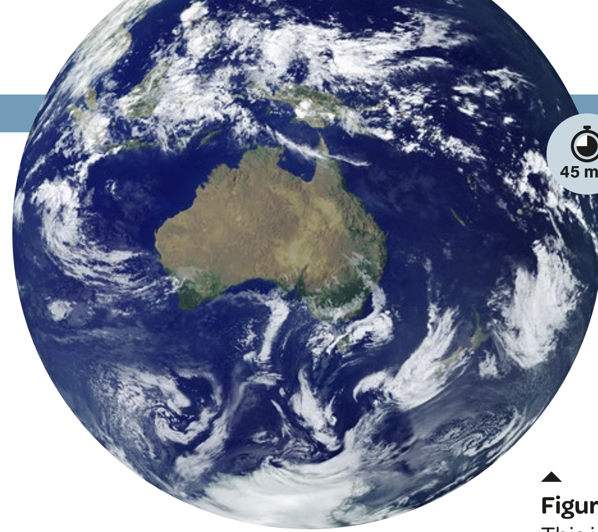


Figure 18.7: This is the reality from space.

Process: Analysing data and information

Focus: Evaluating conclusions based on data

The internet and social media are full of claims that range from the reliable to the outrageous. It is important to examine the evidence to decide if a claim is scientific, valid and reliable, or pseudoscience with no scientific basis.

Hint: Consider what the claim is saying, and if the person or group making the claim has reliably sourced data they can present as evidence.

Aim

To investigate a claim that is supposedly backed up by evidence and determine if the claim is science or pseudoscience

Materials

- device with internet connectivity

The claim

The claim is that Earth is flat and not a sphere.

1 A flat-Earth conference is held in the United States every year and about 600 people attend, including some non-believers who were overwhelmed by the passionate flat-Earth proponents.
2 The International Flat Earth Society was founded in the mid-1950s in the United Kingdom. Although it was not well supported at the time, in the early 2000s there was a resurgence, via the internet, and conferences were held.
3 The most famous flat-Earth proponent was the writer Samuel Rowbotham. In the 1800s, he proposed that Earth was a flat immovable disc, centred at the North Pole, with Antarctica replaced by an ice wall at the disc boundary.
4 Another model is that the flat planet is encased in a huge hemispherical snow globe.
5 The Sun and Moon move in circles around the North Pole, creating night and day.
6 The Sun and the Moon are 50 km in diameter and circle flat Earth at a height of 5500 km.
7 In a survey conducted in Brazil, 7% of the population believed Earth to be flat.

Method

Refuting the claim that the Earth is flat:

1 Copy the results table, adding a title.
2 Search the internet and find evidence of the first time Earth was proven to be spherical.
3 Find evidence that refutes the claims made in the previous section that Earth is flat.
4 Find five theories and pieces of evidence that indicate Earth is not flat. Record this data in a results table.

Table 18.7: Results

Piece of evidence	Data relating to the evidence	How it supports the idea that Earth is spherical

Questions

1 Identify two of your pieces of evidence which support that Earth is round.
2 Describe some of the quantitative data you found that helps to show Earth is round.
3 Explain how pseudoscientific claims can become widespread in popular media.
4 Discuss an investigation you can conduct to show that Earth is round.
5 Evaluate the claim 'Earth is flat', based on the data you have collected.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Investigation 8.8

45 min

How big is big data?

Process: Analysing data and information

Focus: Describing trends from collected data

Big data is often described in terms of petabytes. But it is not easy to understand just how much that is. What trends can you see that help you to understand the size of big data datasets?

Hint: *Use powers of 10 and scientific notation. More information on scientific notation is available in the Science how-to section on pages 455–56.*

Aim

To determine how large big data is in terms that are easily understood

Materials

- calculator
- workbook
- pen

Method 1: Calculating the information stored in petabytes

1 Show with calculations, in scientific notation, that there are 10^{15} bytes in a petabyte.

2 An A4 page of data takes 2 kilobytes to store. Complete the table to find the number of typed pages in a petabyte.

3 A DVD can hold 4.7 gigabytes of data. Calculate the number of DVDs needed to store 1 petabyte of data. Round your answer to the nearest 100 000. If a DVD is 1.2 mm thick and they are stacked on top of each other, calculate the height of the stack of DVDs.

Method 2: Calculating the volume of big data

There is a huge amount of data sent or posted every minute: 3 million emails, 4500 SMS messages, 700 000 WhatsApp messages, 70 000 Google searches, 55 000 Facebook posts and 5500 tweets. Use this information to answer these questions.

1 It is claimed that more than 1.5 days of time is spent typing the 4500 SMS messages sent every minute. The average time to write and send an SMS message is 30 seconds. Use calculations to determine the accuracy of the claim.

2 Calculate the amount of time spent on the SMS messages sent in one day.

3 The average time to type and send an email is 5 minutes. Calculate the amount of time needed to write the 3 million emails sent every minute.

4 Calculate the number of emails sent in a 24-hour period, and the total amount of time spent on writing these emails.

Method 3: Calculations on stealing big data

There are many instances of hackers breaking into computer systems and stealing data. Suppose that, recently, 800 terabytes were stolen. Assume a download speed of 200 megabytes per second.

1 Calculate how long it would take to download the data.

2 If the data is sold, calculate how long the upload would take at 20 megabytes per second.

3 If the data was copied onto 4 terabyte hard drives at 150 megabytes per second, how long would it take and how many hard drives would be needed?

Table I8.8: Data storage

Data	Conversion	Number of A4 typed pages
1 petabyte	1000 terabytes	
1 terabyte	1000 gigabytes	
1 gigabyte	1000 megabytes	
1 megabyte	1000 kilobytes	500
1 kilobyte	1000 bytes	0.5

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Investigation 8.9

45 min

How to use big data

Process: Analysing data and information

Focus: Explaining relationships between data and information

You will do some research to find out how major corporations use big data to enhance their business. This will be compared to their share prices and used to explain the link between using big data and profits.

Hint: Many large corporations use big data. How would you expect their profits to look if their data analysis was successful?

Aim

To use secondary sources to determine how big data is used by corporations

Materials

- device with internet connection

Background information

You will research some major companies and find out how they use big data to improve their business. Here is an example using Amazon.

Amazon

If someone buys a product, puts it in the cart or even just looks at it, Amazon will use that data. The company will use the data to learn what each customer wants and likes and recommend that product or similar products when the customer returns to the shop. This is how the company earns 35% of its annual sales. Using big data in this way to improve the customer's experience can change the price up to 2.5 million times a day.

- Historical daily share price chart and data for Amazon since 1997 adjusted for splits and dividends. The closing stock price for Amazon at August 2024 was $**166.94**.
- The all-time high Amazon stock closing price was $**200.00** on **2 July 2024**.
- The Amazon 52-week high stock price is $**201.20**, which is **20.5%** above the current share price.
- The Amazon 52-week low stock price is $**118.35**, which is **29.1%** below the current share price.
- The average Amazon stock price for the last 52 weeks is $**162.18**.

Method

1. Search the internet to find three examples of companies using big data.
2. Determine what aspects of data they are using and how they are using the information.
3. Find the total turnover or profitability of the company.

Questions

1. Identify the three companies you have chosen to research.
2. Describe how the companies use big data.
3. If the companies are listed on the stock market, search for a history of their share prices over the past 5 years. Explain what this tells you about the company.
4. Construct a table and record each company's historical share prices.
5. Construct an appropriate graph to show the data from your table.
6. Compare the consistency of the share prices of all three companies and describe any trends in the data from your graph. Discuss what this tells you about how effectively they have used big data.

Conclusion

Copy and complete:
'The results show that …' *(respond to the aim).'*

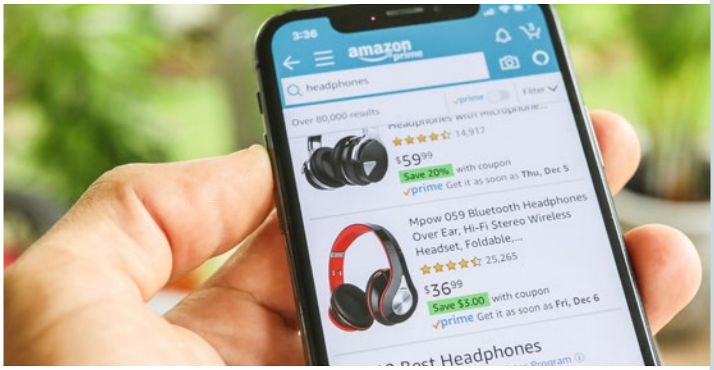


Figure 18.9: Using your phone to look at products on Amazon sends the company data, which it then uses to generate targeted advertising geared to your particular interests.

Investigation 8.10

State of Origin

Process: Analysing data and information

Focus: Evaluating conclusions based on data

In this investigation, you will analyse data for the New South Wales and Queensland Women's Rugby League State of Origin teams by using univariate and bivariate techniques to see if one team has a statistical advantage over the other.

Hint: *What results would suggest that one team might have an advantage, if the data is compared?*

Aim

To determine if one team has a physical statistical advantage

Materials

- Excel spreadsheet and calculator
- provided data and information

Table I8.10a: Queensland Women's Rugby League data, 2022

Name	Height (cm)	Weight (kg)	Age (years)
Zahara Temara	175	75	25
Tamika Upton	178	71	25
Tiana Raftstrand-Smith	173	84	19
Evania Pelite	169	80	27
Romy Teitzel	176	72	23
Shenae Ciesiolka	171	65	25
Destiny Brill	178	73	19
Jessika Ellston	175	81	25
Tarryn Aiken	167	61	23
Chelsea Lenarduzzi	178	95	27
Lauren Brown	169	69	27
Keilee Joseph	164	75	21
Julia Robinson	170	73	25
Shannon Mato	172	82	24
Tazmin Gray	174	80	27
Emily Bass	161	66	24
Stephanie Hancock	172	88	40
Tallisha Harden	178	84	30
Sara Sautia	172	79	20
Brittany Breayley-Nati	167	69	31
Ali Brigginshaw	178	68	33
Karina Brown	168	70	33

45 min

Method

Use the data from spread 8.10 on the 2022 NSW Women's Rugby League team and the data in Table 8.6 to complete the activity.

Questions

1 Calculate the mean and range for the Queensland team and put the results in Table I8.10b.

Table I8.10b: Results for Queensland team

Value	Height (cm)	Weight (kg)	Age (years)
Mean			
Range			

Table I8.10c: Results for NSW team

Value	Height (cm)	Weight (kg)	Age (years)
Mean	170	75	25
Range	29	35	11

2 Compare the results for each team and make three comments about this univariate data.

3 Enter the Queensland data for height and weight into Excel to construct a scatter plot for the data. Is there a clear relationship between height and weight? Explain.

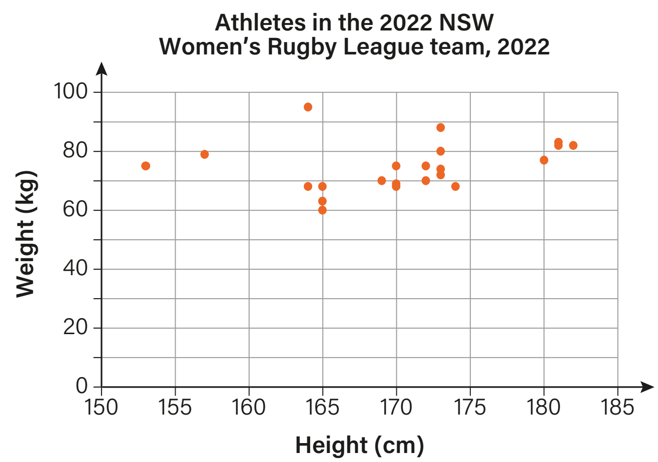


Figure I8.10: NSW Women's Rugby League 2022 team scatter plot

4 Discuss any similarities and differences between the two teams.

5 Based on your calculations, evaluate the claim 'The Queensland Women's Rugby League team has a significant advantage over the NSW Women's Rugby League team.'

Conclusion

Copy and complete:

'The results show that … *(respond to the aim)*.'

Investigation **8.11**

Heads and tails

Process: Analysing data and information

Focus: Explaining relationships between datasets and information

Tossing a coin has two equally likely outcomes and it is often thought of in terms of each outcome appearing an equal number of times. Sometimes the same outcome occurs multiple times. You will be creating a spreadsheet that simulates tossing a coin 20 times.

Hint 1: Look at the longest winning streak.

Hint 2: Is the number of tails 10 every time? Why or why not?

Aim

To determine if equally likely outcomes occur an equal number of times in an experiment

Materials

- 1 coin
- Excel spreadsheet

Method

1 Record a prediction about the number of heads (H) and tails (T) you are going to toss. Your total number of tosses should add up to 20.

2 Toss a coin 20 times, noting down the result. Count the number of tails and the longest streak of either heads or tails.

  a Compare your result with those of other members of your class.

  b Calculate the mean of all the number of tails. Is it close to 10? Explain your answer.

3 Open a new Excel spreadsheet and follow these instructions to create the spreadsheet activity.

  a Type the words:
  - 'Winning streak' into cell B1
  - 'Total tails' into cell E1
  - 'Winning probability is ½' into cell B2
  - 'Random number' into cell A4
  - 'Game number' into B4
  - 'Result' into C4.

  b Type these formulas:
  - =INT(RAND()*2)
  - =IF(A5=0,"head","tail")
  - =IF(A5=0,"end streak","streak continues")
  - =COUNTIF(D5:D24,"streak continues")

  c Type the number from cell F1 into cell B5, then after the next trial type the number from cell F1 into cell B6 and continue until you have filled in the 20 trials down to cell B24. Use these values for the number of tails to complete the calculations in the questions section.

  d Write down the value of the longest winning or losing streak for each trial until you have the 20 values.

  e Press the F9 key to recalculate the winning streak.

4 Describe what you notice about the number of tails each time. Compare this to your actual coin toss and comment.

Questions

1 What was the total of tails and longest winning streak from the 20 heads and tails you wrote at the start?

2 Use the F9 key to recalculate and complete the experiment 20 times, recording the total tails and the longest winning streak for each trial.

3 Compare your original results with the results from the spreadsheet. Make a comment about the comparison.

4 Calculate the mean and range for the total won in the 20 simulations. Compare your results with those of the other members of your class.

5 Calculate the mean of all the trials for your class. Is that mean closer to 10? Discuss.

Conclusion

Copy and complete:

'The results show that ... *(respond to the aim)*.'

45 min

	A	B	C	D	E	F
1		Winning streak			Total Tails	9
2		winning probability is1/2				
3						
4	random nu	Game number	Result			
5	1	1	tail	streak continues		
6	0	2	Head	end streak		
7	1	3	tail	streak continues		
8	0	4	Head	end streak		
9	1	5	tail	streak continues		
10	1	6	tail	streak continues		
11	1	7	tail	streak continues		
12	0	8	Head	end streak		
13	1	9	tail	streak continues		
14	0	10	Head	end streak		
15	1	11	tail	streak continues		
16	0	12	Head	end streak		
17	0	13	Head	end streak		
18	0	14	Head	end streak		
19	0	15	Head	end streak		
20	0	16	Head	end streak		
21	1	17	tail	streak continues		
22	0	18	Head	end streak		
23	1	19	tail	streak continues		
24	0	20	Head	end streak		
25						

Figure I8.11a: Your Excel spreadsheet should look like this.

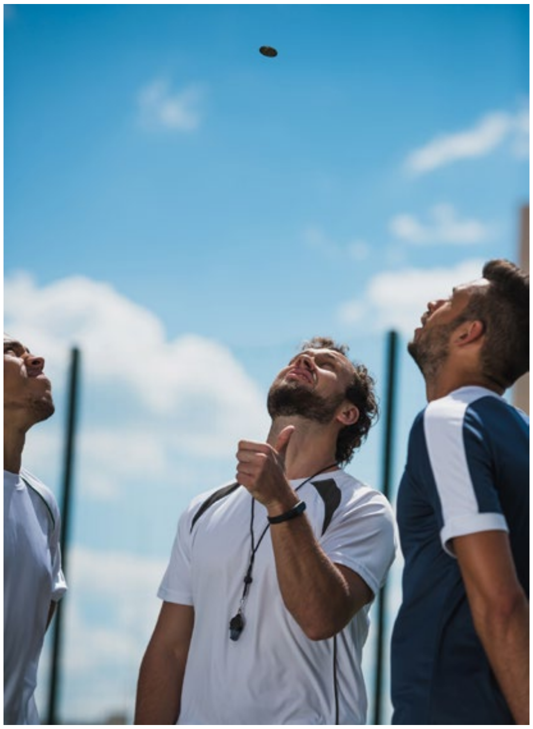


Figure I8.11b: You have an equal chance of winning or losing on a coin toss.

Investigation 8.12

What is your temperament?

Process: Problem-solving

Focus: Evaluating claims based on evidence

The Ancient Greeks theorised that there were four fundamental bodily aspects – blood, yellow bile, black bile and phlegm. It was thought that if a person became unbalanced, they could become ill. In this investigation, you will examine these aspects of temperament to evaluate their merit.

Hint 1: *Consider the evidence behind the claim the website is making.*

Hint 2: *How could you ensure that the claims of temperament types are valid?*

Aim

To use an online survey to determine your temperament and use statistical analysis to decide if it is science or pseudoscience

Materials

- You will engage in an online personality test to determine your temperament.
- The survey consists of 24 statements that you answer on a 5-point scale from *strongly disagree* to *strongly agree*. It should take 5–10 minutes to complete.

Method

1 Complete the survey and determine your temperament.

2 The four temperament descriptions are:

Sanguine

- Sanguine people are extroverted and sociable. They are cheerful people who see a glass as half-full instead of half-empty. You will probably find them in the middle of a crowd and not at the fringes. Social interactions come easy to them, and they can be talkative and energetic.
- Although sanguine people seem to have positive traits, the same personality traits that make them fun to be around can also make them impulsive and indecisive. Their impulsivity can sometimes manifest as seeking out thrill-seeking behaviours, which in extreme cases could include drug use.

Choleric

- Choleric people are dominant and assertive. They are goal-oriented and driven. They are high achievers at work, school or even at play, and are often selected as team leaders.
- The decisiveness that people with a choleric temperament often display can also manifest as impatience and stubbornness. This may mean their personal and social relationships can be impacted by their need to achieve goals they have set themselves.

Phlegmatic

- Phlegmatic people are easy-going, laid-back and patient. They display empathy in their relationships with others. As they are most comfortable with simple routines, they will try to avoid conflict. This makes them reliable, but their lack of assertiveness can also make them appear passive and unfeeling.

Melancholic

- 'Melancholy' doesn't necessarily mean 'sad' or 'without joy', though someone with a melancholic temperament may become moody or anxious if things are not to their liking. Typically, they may just be thoughtful and sensitive. This temperament can be expressed as a tendency to be methodical and analytical, which are valued attributes in work situations. However, a melancholic person's reserved manner may mean they prefer to work on their own, rather than as a member of a workplace team.

45 min

Questions

1 Do you agree with the result? Explain your answer.

2 Does the description of your temperament match your actual personality?

3 Consider the other members of your class with the same result for temperament and decide if your personalities align.

4 There would have been some responses in the survey that you were unsure about. Redo the survey, responding to the statements differently and see if your alleged temperament result changes.

5 What is your view of the validity of the temperament survey to determine personality?

6 Consider other students who got the same temperament result as you. Comment on the reliability of the survey.

Conclusion

Copy and complete:

'The results show that ... *(respond to the aim).*'

Figure 18.12: Different emotions are sometimes linked to specific temperaments in online tests.

Glossary

A

abiotic: non-living

absolute dating: determining the age range of an object, such as a fossil, in numbers of years

absorption: when light is not reflected by a substance but instead is turned into energy

acceleration: a change in speed over time

accuracy: how close a measured value is to the true, exact value; how closely a recorded value matches the expected outcome of an investigation.

acid: a substance with a pH of less than 7

activation energy: the energy required for successful collisions and a chemical reaction to occur

adaptive immune system: specific disease responses that target individual, recognised pathogens

addition polymerisation: a reaction in which alkenes join together at the carbon–carbon double bond to form organic polymers

aerophone: an instrument that produces sound by causing air to vibrate

alkali: a base that is dissolved in water

alkane: a hydrocarbon containing only single covalent bonds

alkene: a hydrocarbon containing a double covalent bond

alkyne: a hydrocarbon containing a triple covalent bond

allele: a variation of a gene

alloy: a metallic substance made of a metallic element and at least one other element, usually a metal

alpha particle: a particle made of two protons and two neutrons

alpine: areas of high elevation

alternator: a device that converts kinetic energy into electrical energy

amino acid: an organic molecule that is the building block of a protein

ammeter: a device that measures electric current

amplitude: the height of a wave measured from its midpoint

andesitic hornfels: a dark, fine-grained metamorphic rock known for its distinct green colouring and hardness

anecdotal evidence: evidence without scientific basis and usually in the form of personal accounts

angle of incidence: the angle at which light hits a surface

angle of reflection: the angle at which light reflects from a surface

anion: a negatively charged ion

antibody: a protective protein produced by the immune system to neutralise a specific infectious pathogen

antimatter: particles that have properties opposite to that of normal matter

aqueous: dissolved in water, or in an aqueous solution

asexual reproduction: reproduction in which a single parent produces a genetically identical offspring

asphalt: a mixture of gravel, sand and bitumen, used for roads

atmosphere: the layer of gas that surrounds Earth and is 600 km thick

atom: the smallest particle of a chemical element; made up of electrons, protons and neutrons

atomic number (Z): the number of protons in an atom

audiogram: a graph from a hearing test showing the frequency and loudness a patient can hear

average speed: the speed averaged for an entire journey

axon: a long fibre that is part of a neuron that carries electrical impulses away from the neuron

B

balanced forces: forces acting on an object are equal and cancel out, so that motion remains the same

base: a substance with a pH of more than 7

beta particle: a high-energy, high-speed electron

biased data: data that is incomplete, skewed or inaccurate

big bang theory: the theory which states that the universe began as a single point that expanded and is still expanding

big data: large, diverse sets of information that grow at increasing rates

binary fission: cell division in single-celled organisms that produces offspring identical to the parent

binding agent: a substance that holds other materials together to form a cohesive whole

bioaccumulation: the build-up of chemicals such as microplastics in the tissues of living organisms

biodegradable: can be broken down (e.g. by bacteria)

biodegrade: to degrade naturally through the action of microorganisms

biodiversity: the variety of organisms in an ecosystem

biofuel: a fuel derived from biomass such as plants and animal waste, rather than from fossil fuels

biogeography: the study of the past and present distribution of living organisms

biomagnification: increasing concentrations of chemical toxins in organisms up the food chain

bioplastic: a plastic made from a biological material

biotechnology: using living organisms to develop products

bitumen: the heaviest fraction of crude oil, left over after fractional distillation

bivariate data analysis: statistical analysis that compares data based on two characteristics or variables

Bohr diagram: a diagram showing the electron configuration of an atom

bore: the hollow in the centre of a tube

box-and-whisker plot: a graph that displays numerical data in quartiles; it is a useful way to compare sets of data

by-product: an unwanted or waste product of a process

C

carbon cycle: the natural cycling of carbon through ecosystems

carbon sequestration: the process of capturing and storing atmospheric carbon dioxide

carbonate: a substance containing the elements carbon and oxygen

catalyst: a substance that increases the rate of a chemical reaction without being used up

cation: a positively charged ion

causation: when one variable causes an effect in another variable

caustic: able to burn or corrode organic tissue through chemical action

cell cycle: the process a cell goes through every time it divides

central nervous system: the brain and spinal cord

chain reaction: a series of reactions in which the product of one reaction is the reactant of the next reaction

chemical barrier: a defence that can kill pathogens that land on or attempt to enter the body

chemical bond: an electrostatic force that connects atoms to one another

chemical equation: a chemical reaction represented using chemical formulas of reactants and products

chemical formula: chemical symbols showing the ratio of elements to one another in a compound; an expression of the elements that make up a chemical compound, usually presented as a ratio using letters and numbers; for example, H_2O

chromosomal mutation: a mutation caused by a change to a large section of a chromosome

chromosome: a tightly coiled strand of DNA

circuit: a closed path for transmitting electricity, including connecting wires and components connected to a power source

citation: a way of giving credit to a source, usually in the same text where the information appears

claim: what you want to tell other people about and get them to believe

climate: trends in weather over a period of at least 30 years

climate zone: a region with a specific climate

clone: a gene or an organism that is genetically identical to its parent

closed system: a system from which energy can flow in and out but matter cannot

cochlea: the organ of the inner ear that converts sound energy into nerve messages

coefficient: a number placed before the chemical in a formula or chemical equation

collision theory: a theory which states that for a chemical reaction to occur, particles must collide with the correct orientation and with enough energy; can be used to predict the rate of reactions

combustion: a reaction that involves burning in the presence of oxygen to release heat

common ancestor: an ancestor that is shared by two or more independent species

comparative anatomy: the study of similar anatomical structures in different species in order to understand their evolution

comparative embryology: the study of the similarity of the embryos of different species as they develop

component: a device in a circuit that uses electrical energy

compound: a pure substance made up of two or more types of atoms bonded in fixed ratios

compression: an area in a wave where particles are close together

concave: hollowed or rounded inwards

concentration: the amount of a substance in a volume of solution

condense: to change from a gas to a liquid state

conductor: a material that allows the movement of charge

cones: light receptors in the retina that detect coloured light

conservation of mass: mass cannot be created or destroyed

constant: remains the same

contact process: the multistep industrial process of producing sulfuric acid

continuous data: data that can take any value along a continuum or between fixed values

control: a method that can be used to prevent or treat a disease

control rod: a rod inside a nuclear reactor that absorbs neutrons to control the chain reaction

conversion factor: a number used to change one unit of measurement to another

convex: curved or rounded outwards

coral atoll: a ring-shaped island formed by a coral reef

coral bleaching: a phenomenon where corals lose their colour due to the absence of symbiotic algae

correlation: a mutual relationship between two things that may or may not be causal; a relationship between two factors or variables that shows them changing together, in either the same or the opposite way

corrosion: the degradation of a metal due to reacting with its environment

corrosive: highly reactive and damaging or destructive to another substance

Country: a complex concept that can include lands, waterways, coastlines, the sky and stars; also the complex lore, law, place, custom, tradition, spirit, culture, language, family and identity that are part of First Nations' cultures and knowledges

covalent bond: a bond in which two atoms share one or more pairs of electrons

covalent network solid: a continuous network of atoms that are joined together through covalent bonds (not discrete); also called 'giant covalent solid'

crossing over: the exchange of genes by homologous chromosomes

cross-links: chemical bonds that join polymer chains to one another

crude oil: a naturally occurring liquid fossil fuel that can be refined to produce many different chemicals

crystalline: having the structure and form of a crystal

crystalline solid: a solid with a highly ordered arrangement of particles at the microscopic and macroscopic levels

current: a measure of the flow of charged particles such as electrons in a circuit

D

data: facts and information collected for reference or analysis; a collection of information gathered through observations, measurements, study or analysis

data error: inaccurate data

data point (datum): a single identified element in a dataset

dataset: a collection of data, often from numerous trials related to a single factor

deceleration: a decrease in speed over time

decomposition reaction: a reaction in which one reactant breaks down to form multiple products

degradation: deterioration of physical properties of a material

delocalised electrons: electrons that are free to move about the substance

demographic: a particular set of a population (e.g. age, sex, occupation)

denature: to change the three-dimensional structure of a protein so that it no longer performs its function

dendrite: a filament that is part of a neuron that receives the electrical impulse

density: how heavy something is for its size; mass divided by volume

deoxyribonucleic acid (DNA): the carrier of genetic information; located in the nucleus of a cell

dependent variable: the thing that is measured in a first-hand investigation; its value depends on changes in the independent variable

descriptive analysis: an analysis of data to identify patterns and relationships

diatomic molecules: molecules made up of two atoms

diploid: has two sets of chromosomes

direct contact: a method of diseases transmission from one person to another

discrete data: data that can only take certain values; fixed values; for example, a quantity count

disease: a disorder that causes negative symptoms or outcomes in a living thing

displacement: the distance an object moves from its starting position

displacement reaction: a reaction in which an element replaces (displaces) another element from a compound

dissociate: to split apart into ions in water; to dissolve ionic compounds

distance: the total length an object travels

dominant allele: an allele that only requires one copy to be seen in a phenotype

dominion: to have power or control over another thing

Doppler effect: a change in frequency as an object moves towards or away from an observer

dosimeter: a device used to measure an absorbed dose of ionising radiation

double covalent bond: two pairs of electrons shared between two atoms

double-displacement reaction: a reaction in which parts of two compounds replace each other to form two new compounds

double helix: the structure of a DNA molecule; a double-stranded spiral

Dreaming: a complex term that describes the ways that Aboriginal and Torres Strait Islander Peoples relate to themselves, each other, and the human and more-than-human realms

Dreaming Stories: complex First Nations stories that hold significant knowledge about history, creation, law, lore, and many other knowledges; have been used by First Nations Peoples for tens of thousands of years to care for Country and to live well

E

ecliptic: the Sun's apparent annual path as observed from Earth

economic consideration: a factor that takes into account the costs to individuals and groups

economy: the system of how a country makes and spends money and provides goods and services

ecosystem service: a benefit to humans provided by an ecosystem

effector: a specialised cell, muscle, gland or organ that performs specific actions in response to a stimulus

efficient: not wasteful

electrolysis: passing electricity through a substance to break it up

electromagnetic spectrum: all the different electromagnetic waves

electron: a negatively charged particle in an atom

electron configuration: the organisation of electrons into shells around the nucleus of atoms

electron shell: the area around the nucleus where a specific number of electrons orbit at a specific energy level

electrostatic force: a force of attraction between positive and negative particles

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

emit: create or put out something, such as a sound

endemic: an outbreak of a disease in a specific geographical area

energy: a measure of the ability to do work

energy consumption: the amount of energy used, measured in kilowatt-hours (kWh)

energy efficiency: how much usable energy is produced compared to how much energy has been supplied

energy tariff: the price of electricity purchased from the electricity company, in cents

energy transfer: the movement of energy from one place to another without changing form

energy transformation: a change from one type of energy to another

enhanced greenhouse effect: an increase in the greenhouse effect due to human greenhouse gas emissions

environmental factor (disease): an agent that is present in a person's surroundings

environmental factor (genetics): something in the environment that affects gene expression

enzyme: a protein that increases the rate of a specific chemical reaction in the body

epidemic: an outbreak of a disease in several populations in one geographical area

equation: a mathematical statement which 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

ethical consideration: a factor that takes into account what is right and what is wrong; in science, minimising harm to those involved and ensuring that investigations are conducted honestly and data is collected and recorded accurately

eutrophication: an excess of nutrients in a water body that leads to excessive algal growth

evaluate: judge value based on scientific evidence

evidence-based: a strategy or conclusion that is drawn from information taken from data

evolution: the way in which organisms change over generations as a result of adaptations that suit their environment

exothermic: a reaction that releases energy into the surroundings, causing the temperature to rise

experimental data: information collected by a measurement from a scientific experiment or controlled study

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

expression: the process of converting the instructions in DNA into a trait, such as a protein

eye: an organ of the body that detects light

F

fair test: a test where all variables are kept the same, except for the independent variable and the dependent variable

feedstock: a chemical used to support large-scale chemical reactions, usually in industry

finite: limited in size or amount

first-hand investigation: an investigation where the data is collected by the investigator

fission: the splitting of a heavy atom into two lighter ones

force: a push, pull or twist, measured in newtons (N)

fossil: the geologically altered remains of a previously living organism

fossil fuel: an energy source made of ancient fossils

fossil record: a record of all fossils that are on Earth

fraction: a part of a larger mixture of many parts

fractional distillation: the separation of a mixture into different parts or fractions, according to their different boiling points

fractionating column: a vertical cylinder that decreases in temperature up the column, condensing and separating substances just below their boiling points

frequency: the number of waves that pass a point every second

friction: a contact force that opposes motion; caused by objects rubbing against each other

fuel cell: a device that converts hydrogen and oxygen into electricity

functional group: an atom, a group of atoms or a specific feature that is responsible for the chemical properties of a compound

fusion: the joining of two lighter atoms to form a heavier one

G

gamete: a sex cell – an ova or a sperm

gamma radiation: high-energy electromagnetic waves

gene: a segment of DNA, the basic functional unit of heredity

general formula: a formula that represents the atomic composition of members of a class of compounds

generate: to make or produce something

genetic diversity: the range of genes present within a population or species

genetic technology: a technology used by scientists to study or alter living things

genetics: a trait or characteristic that is passed from a parent to an offspring

genome: an organism's entire sequence of DNA

genotype: the genetic code for an organism

giant network solid: a continuous network of atoms joined together through covalent bonds (not discrete); also called 'covalent network solid'

glacier: a slowly moving mass of ice formed by the accumulation of snow.

gland: a tissue that secretes hormones

Gondwanaland: the supercontinent that broke from Pangaea approximately 250 million years ago and was made up of the modern-day continents of Africa, South America, Australia and Antarctica

greenhouse effect: the trapping of the Sun's heat by Earth's atmosphere

greenhouse gas: a gas that traps the Sun's heat in Earth's atmosphere

greenhouse gas emission: the production of a greenhouse gas

groundwater: water that flows underground in spaces between rocks and within soils

H

habitat: the place where an animal or plant naturally lives

half-life: the time for half of a sample of radioactive isotopes to decay

haploid: has a single set of chromosomes

Hawthorne effect: the fact that people change their behaviour if they know they are being observed

hazard: something that can harm living things, objects or the environment

health: in First Nations health care, holistic wellbeing, including mental and social health

heat pump: a device that moves heat from one place to another

herd immunity: the indirect protection from an infectious disease that happens when many people in a population are immune either through vaccination or through previous infection

heredity: the passing on of traits from parents to their offspring

heterozygous: a genotype of two different alleles

homeostasis: maintaining a balanced internal environment, by responding to changes in the external environment

homologous: chromosomes that have the same genes in the same order

homologous series: a class of compounds with the same functional group and whose members differ by $-CH_2-$

homologous structures: features in different organisms that are similar in structure, but different in function

homozygous: a genotype of two of the same allele

hormone: a chemical secreted by a gland that triggers a response in certain cells

host: a large organism that is infected by or harbours a smaller organism

hybrid: a combination of two or more things

hydrocarbon: an organic compound made up of only carbon and hydrogen atoms

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

I

idiophone: an instrument that produces sound through vibrating itself

immune system: a network of cells and tissues that help to prevent and fight diseases in the body

immunisation program: a series of vaccinations given to individuals to help prevent specific infectious diseases in populations

impersonal: without personal feelings; in health care, being treated like an illness rather than a person

implication: the effect a decision will have on other factors relating to it

incidence: the number of new cases of a disease in a population

independent variable: the thing that is deliberately changed in a first-hand investigation; its value does not depend on any other variable

indicator: a substance used to determine the acidity of a solution

Industrial Revolution: a period in the late 1700s when manufacturing transformed to large-scale factories that were powered by the burning of fossil fuels

inert: chemically unreactive

inertia: a property of matter that causes it to resist change in speed or direction (to remain at rest or in a state of uniform motion)

infectious: can be transmitted between individuals

influencer: a person with an online following who promotes products or services through social media to their followers to influence their purchasing behaviours

infrasound: low-frequency sounds below 20 Hz

innate immune system: general mechanisms of the immune systems that target any foreign substances in the body

inorganic compound: a substance that does not contain carbon–hydrogen bonds

instantaneous speed: the speed at a particular time in a journey

insulation: a material or substance that does not allow heat to pass easily through it

insulator: a material that resists the movement of charge

intermediary: a link between two hosts that allows a pathogen to move indirectly between them

inversely proportional: as one quantity increases, the other decreases

investigable question: a clear, concise question that contains a single independent and dependent variable, and centres the research for an investigation

ion: an atom with unequal numbers of protons and electrons; an atom with a positive or negative charge

ionic bond: an electrostatic force between a cation an and an anion

ionic salt: a compound made up of a cation and anion

ionise: to remove an electron from an atom

ionising radiation: radiation, made up of particles, X-rays or gamma rays, that has enough energy to cause cancer

iron oxide: a dark red solid that exists as the mineral haematite and is the main component of rust

isolation: when a population is cut off from others

isotopes: atoms of the same element with the same number of protons but a different number of neutrons

IUPAC: International Union of Pure and Applied Chemistry

J

joule: the unit of energy

JSON: JavaScript Object Notation; a standard text-based format for storing and transmitting data in web applications

K

karyotype: a picture of an organism's full set of chromosomes

kinetic energy: the energy of movement

L

landfill: disposal of waste by burying it

lattice: a three-dimensional repeating structure or pattern

law of conservation of energy: a scientific law which states that energy is never created or destroyed; it can only change into different forms

life-cycle analysis: a way to consider the impact of a device from its creation, while in use and when disposed of

line of defence: the different levels of defence that the body mounts to prevent and destroy infectious diseases

load: a component of a circuit that uses electrical energy

locant: a number that indicates the carbon where certain parts of an organic compound are positioned

longitudinal wave: a mechanical wave in which the particles of the medium vibrate in the direction the wave is moving

long-sighted: a condition of the eye where light focuses behind the retina

lymphocyte: a white blood cell that can produce antibodies and destroy infected body cells

M

made resource: a resource that is manufactured from natural resources

magnitude: the size of a measurement

mass: the amount of matter in an object, measured in grams (g) or kilograms (kg)

mathematical formula: a rule or principle that helps you to find the answer to a question or understand the relationship between variables

matter: a substance made of particles

mean: a measure of centre (an average) calculated by adding all the numbers together and dividing by how many numbers there are

mechanical wave: a wave that moves energy through matter by vibrating particles

median: the middle number in a set of numbers when they are arranged in order

medium: a substance through which a wave can travel

megafauna: the large mammals and marsupials that roamed across the continent of Australia and became extinct during the latter part of the Pleistocene period

megapode: a class of flightless bird that had large legs and feet and built nesting mounds in which to lay its eggs

meiosis: complex cell division that produces unique haploid gamete cells

membrane: a thin layer of body tissue made of cells

membranophone: an instrument that produces sound through a vibrating, stretched membrane

meniscus: the curve seen at the top of a liquid in its container

menstruation: monthly discharge of blood and tissue from the lining of the uterus

metal ore: a metallic mineral deposit that is profitable to mine

metallic bond: a bond in which free electrons move around metal ions

meteorologist: a scientist who studies the atmosphere and its effects on Earth, including weather patterns

microbeads: a type of microplastic with a specific function for scrubbing or exfoliating

microplastics: tiny plastic particles from the physical breakdown of larger plastics

mineral deposit: rocks that contain a particular mineral in large amounts

mineral reserves: parts of a mineral resource that can be mined economically

mitosis: simple cell division that produces identical cells

mode: the number that appears most frequently in a set of numbers

molecular formula: a chemical formula for molecules showing the type and exact number of atoms in the substance

molecule: two or more atoms covalently bonded to form a discrete or separate unit of atoms

monogenic: influenced by a single gene

monomer: a small molecule that bonds together in a repeating pattern to form large polymers

mutation: an error in DNA that changes the DNA sequence, which can be caused by DNA replication, or cell division

N

natural resource: a resource that is useful in its natural form

natural selection: the process in which organisms that are better suited to their environment tend to survive and reproduce, passing their traits on to further generations

negative feedback: a response that counteracts a stimulus

net force: the sum of all forces acting on an object

net ionic equation: a chemical equation that only includes the ions and precipitate involved in the reaction; not spectator ions

net zero emissions: when the greenhouse gas emissions that are produced are balanced out by those that are absorbed by other processes

neuron: a specialised cell that carries messages throughout the nervous system

neurosurgeon: a specialist doctor who operates on the brain and nervous system

neurotransmitter: a chemical messenger that carries a chemical message from one neuron to another

neutralisation reaction: a reaction involving an acid and a base to produce water and a salt

neutralise (disease): a response that defends the body from a pathogen by stopping its effects without destroying it

neutralise (chemistry): to make something chemically neutral; neither acidic nor basic

neutron star: the small core left over from the collapse of a massive supergiant star when matter is compressed into a small space

Ngangkari: an Aboriginal healer who has extensive knowledge of bush medicine and the ceremonies and rituals required to achieve the best health outcomes

nitrogenous: containing nitrogen

noble gas configuration: the valence electron configuration that occurs through chemical bonding

non-infectious: cannot be transmitted between individuals

non-investigable question: a question that cannot be investigated scientifically

non-renewable: finite, and will run out

normal: a line at right angles to the surface of a substance

normal force: the force of the ground pushing up in opposition to gravity

NoSQL: non-relational database system; a database that does not have rigid systems and can store petabytes of data in a format other than tables that enables quick processing of large data volumes and multiple concurrent queries

nuclear reaction: a reaction that involves the nucleus of atoms

nuclein: a name given to DNA when it was first discovered

nucleotide: the building block of DNA, consisting of a sugar, a phosphate and a nitrogenous base (adenine, guanine, thymine or cytosine)

nutrition: the intake of nutrients that are necessary for health and growth

O

observational study: a type of study in which individuals are observed or certain outcomes are measured

ocean acidification: a decrease in the pH of the oceans due to the absorption of more carbon dioxide

ocean circulation: the movement of water in the oceans due to major currents

octet rule: the tendency of atoms to achieve eight electrons in their valence (outer) shell to be stable

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

oleum: an intermediate product formed between sulfur trioxide and sulfuric acid, to make the process safer ($H_2S_2O_7$)

opaque: a material that does not allow any light to pass through

open system: a system that allows matter and energy to flow in and out

optimise: make the most effective us of something

organic chemistry: the study of carbon-containing compounds

organic compound: a substance that contains carbon, commonly bonded to hydrogen

outbreak: a sudden spike in the number of cases of a disease

ovum: a female sex cell, also known as an egg cell (plural ova)

oxidation: a reaction taking place in the presence of oxygen

P

pandemic: an outbreak of a disease in multiple populations in different geographical locations across the world

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: a small part of a type of matter, including an atom or a molecule

patent: a type of legal ownership of intellectual property that gives the owner the right to exclude others from making, using or selling an idea or invention

pathogen: an organism that causes a disease in a host

pattern (data): when data repeats in a predictable way

pedigree chart: a chart that shows the inheritance of a trait through generations of a family

penetrating power: how well radiation from radioactive materials can pass through matter

percentage error: measures how close the experimental value of an investigation is to the theoretical or true value

peripheral nervous system: the part of the nervous system that lies outside the brain and spinal cord

pH: a figure expressing the acidity or alkalinity of a solution

phagocyte: a white blood cell that engulfs and ingests foreign particles and pathogens

phenotype: how the genotype is physically expressed

photosynthesis: the chemical reaction that occurs in the chloroplasts of plants and algae to convert carbon dioxide and water into glucose and oxygen

physical barrier: a mechanism that blocks a pathogen from entering the body

pinna: the outer ear flap

pitch: the frequency of sound, measured in hertz (Hz)

PLA: polylactic acid; a bioplastic polymer made from corn or sugar

plagiarise: to copy someone else's work and present it as your own

plasma: superheated matter consisting of ionised gas

plasmid: a small circular DNA molecule in bacteria and some other microscopic organisms

plasticise: to soften a polymer by adding lubricating chemicals, resulting in a more flexible polymer

plausible: could be reasonably accepted based on available evidence

point mutation: a mutation caused by a change to a single nucleotide base

pollution: a substance that enters the environment and has harmful or poisonous effects

polyatomic ion: two or more ions bonded together and acting as a single charged unit

polyethylene: the common name for the most widely used plastic; IUPAC name 'polyethene'

polygenic: influenced by two or more genes

polymer: a long-chain molecule (usually carbon-based) made up of many small repeating units

polymerisation: a reaction in which monomers combine chemically to form long-chain molecules

population: a group of organisms of the same species that live and interact within the same area

positive feedback: a response that amplifies a stimulus

potential difference: the difference in potential energy (voltage) between two points in a circuit

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 x 2 x 2, which is 8, so the *power* of 2^3 is 8

precipitate: an insoluble product that forms a solid in solution

precipitation: liquid or solid water that forms in the atmosphere and falls to Earth's surface

precipitation reaction: a type of double displacement reaction that forms a precipitate when two solutions are combined

precision: how close measured values are to each other within a dataset

prefix: letters or numbers placed before the stem of a word

prevalence: the total number of cases (new and existing) of a disease in a population

product: a substance formed in a chemical reaction

proportional: as one quantity increases, so does the other

proteins: long polymer chains made up of amino acid monomers

pseudoscience: beliefs mistakenly regarded as being based on scientific theory

Punnett square: a diagram that shows the possible genotypes of offspring

PVC: polyvinyl chloride

Q

qualitative data: data with qualities or characteristics that can be observed and described

quantitative data: information based on numbers that can be counted, measured or represented by numbers

quarantine: separating and restricting the movement of people who have been exposed to an infectious disease to see if they become sick

R

radioactive tracer: a radioisotope used to track or trace the path of a substance

radioisotope: an isotope that emits radiation

radiopharmaceutical: a drug with a radioisotope attached

radiotherapy: a therapy that uses radiation to kill cancerous cells

randomised controlled trial: a study in which a number of similar people are randomly assigned to two (or more) groups to test a specific drug, treatment or other intervention

range: in a set of numbers, a measure of spread between the highest number and the lowest number

rarefaction: an area in a wave where particles are spaced out

ratio: a way of comparing like quantities without units

reactant: a substance at the start of a chemical reaction

receiver: a device that receives or detects sound

receptor: a specialised cell or organ that detects changes

recessive allele: an allele that requires two copies to be seen in a phenotype

reciprocal: the reciprocal of a number is 1 divided by that number

recombinant DNA: DNA that has been formed by inserting or combining genes from different organisms

recycle: to convert waste into reusable materials

redshift: a change in light's wavelength towards the red end of the visible spectrum

reflect: send back sound or light without absorbing it

reflection: when light is bounced off a surface

refraction: when light is bent as it passes from one substance to another

relationship: a link between two factors

relative dating: arranging geological objects and rocks in a sequence from oldest to youngest

reliability: when repeated trials provide consistently similar results

reliable data: data that is consistently similar when multiple trials of the same investigation (or search) are repeated

renewable: can be renewed, and will not run out

research question: a clear, concise and open-ended question that centres the research for a paper, project, experiment or literature review

resistance: a measure of the opposition to flow of electric current

resource: a source of something that is useful

retina: the inside, back layer of the eyeball that is made of light receptors

ribonucleic acid (RNA): a nucleic acid similar to DNA that helps to produce proteins from the genes of DNA

rods: light receptors in the retina that detect shades of light and allow us to see in black and white

rusting: the corrosion of iron to form iron oxides

S

saturated compound: a compound with only single covalent carbon–carbon bonds

scale factor: the ratio between corresponding measurements of an object and a copy of that object

scattering: light rays are randomly reflected in many directions

science: the study of the natural and physical world through observation, experimentation and testing theories against evidence

scientific argument: an idea supported by facts and evidence to persuade other people

scientific notation: a way to write very large or very small numbers in a simple form

second-hand investigation: an investigation that uses data previously collected in a separate investigation

selection pressure: a factor that can influence which traits are beneficial to the survival of organisms

semen: protective fluid that contains sperm

sensitive data: confidential personal, business or classified information

series circuit: a circuit in which components are connected in a line, so the current has only one path to take

sexual reproduction: reproduction in which gametes from two parents fuse to produce a genetically unique offspring

short-sighted: a condition of the eye where light focuses in front of the retina

single covalent bond: one pair of electrons shared between two atoms

single-displacement reaction: a reaction in which a more reactive element replaces a less reactive element from a compound

singularity: a small dense region of space containing matter

skeletal formula: a shorthand way to represent organic compounds, using only lines and symbols for elements other than carbon and hydrogen

skeleton equation: a chemical equation that has not been completed and/or balanced

smelt: to extract metal from ore by heating and melting

smog: a form of air pollution

social consideration: a factor that affects society and the people within society

social distancing: maintaining a distance from other people to avoid catching or transmitting an infectious disease

social media: online platforms that allow individuals and groups to publicly share content to an audience of followers

solar energy: energy from the Sun

soot: a black form of carbon formed by incomplete combustion

sound: a mechanical wave that transfers energy through vibrating particles

species: a specific form of chemical substance involved in a reaction

spectator ion: an ion that does not take part in the reaction

speed: the distance an object travels divided by the time taken to travel that distance

sperm: a male sex cell

star: a burning ball of gas, mostly hydrogen and helium, held together by its own gravity

star rating: a rating for comparing the efficiency of different appliances

stationary: not moving

stem: the word in the name of an organic compound that indicates the number of carbons in the longest chain

stem cell: an undifferentiated cell

stimulus (plural stimuli): a detectable change in the environment that can be detected by a receptor

strong acid: an acid that ionises completely in water

structural formula: a representation of a compound that shows the structural arrangement of atoms

sublime: to change state from solid to gas without passing through a liquid phase

subscript: a letter or number written slightly below and to one side of another; for example, ‘2’ in H_2O

suffix: a word or letters placed after the stem of the word

supernova: the explosion caused when a star collapses and dies

superscript: a letter or number written slightly above and to one side of another; for example, ‘2’ in 8^2

surface area: the area of the outermost layer of an object

surface tension: where the molecules at the surface of a liquid are more attracted to each other than to the air above the liquid

sustainable: able to be maintained at a certain rate or level

symbiotic relationship: an ecological relationship where both parties cannot survive without the other

synapse: the gap between the axon and dendrite of two neighbouring neurons

synthesis reaction: a reaction in which two or more reactants combine to form a more complex product

synthesise: make something new by combining smaller parts

synthetic: made by humans by non-natural methods

T

technological advances: making improvements to existing ideas in order to find new solutions to problems

temperature inversion: when a layer of hot air in the atmosphere stops circulation of air away from Earth’s surface

theory of evolution by natural selection: a theory that says species have evolved adaptations over time that helped them to survive in their environment

therapeutic: ways of healing

thermal: heat

thermal expansion: the increase of volume of a substance due to an increase in temperature

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

thermoset: a polymer with cross-links; chars when heated instead of melting

transcription: the process in which a cell makes an RNA copy of a piece of DNA

transgenic organism: a living thing that contains recombinant DNA

translucent: a material that allows some light to pass through

transmission: spreading from person to person

transmitter: a device that produces or transmits sound

transparent: a material that allows light to pass through

transverse wave: a wave that vibrates at right angles to its direction of motion

trend (data): when data moves in a general direction, usually up or down

triple covalent bond: three pairs of electrons shared between two atoms

tsunami: a large sea wave caused by an earthquake

tuber: the rhizome part of a plant, which forms underground and is often nutrient rich

U

ultrasound: high-frequency sounds above 20 kHz

unbalanced forces: forces acting on an object are different in size and do not cancel out but cause a change in motion

univariate data analysis: statistical analysis that consists of observations of a single characteristic or variable

unsaturated compound: a compound with at least one double or triple carbon–carbon bond

UV: ultraviolet

V

vaccination: the introduction of a dead or weakened form of a pathogen into the body so that it can produce antibodies that will fight off future infections

vacuum: empty space

valence electrons: electrons that occupy the outermost shell of an atom

valence shell: the outermost shell of an atom

valency: the attracting power of an atom; ion charge

valid data: data that is reliable and accurate and meets the criteria of the investigation

validity: when an investigation measures what it is meant to measure

variable: a factor in an investigation or a model that can be changed, measured or controlled

variation: the difference between individuals in a species, in both genetics and phenotypes

vasoconstriction: the constriction of blood vessels

vector (disease): an organism that carries a disease-causing agent from reservoirs to the host

vector (physics): a quantity that has direction and magnitude

vehicle: a car, bus or truck

velocity: a measure of how quickly displacement changes

vestigial structure: a feature of an organism that has lost some or all of its function through evolution

viscosity: the resistance of a substance to flow or change of shape; high viscosity = low ability to flow (thick)

voltage: a measure of electric potential energy

voltmeter: a device that measures potential difference (voltage)

volume: the loudness or amplitude of sound, measured in decibels (dB)

vulcanised rubber: synthetic rubber that has been modified from its natural form to include cross-links

W

water cycle: the cycle of processes by which water circulates between Earth's oceans, atmosphere, land and biosphere

wave: moving energy

wavelength: the distance from the peak of one wave to the peak of the next wave

weak acid: an acid that partially ionises (loses or gains electrons) in water

weather: what is happening in the atmosphere at a specific place and time

weight: a force acting downwards on a mass due to gravity

word equation: a representation of a chemical reaction using the names of the reactants and products

X

XML: Extensible Markup Language; allows data to be stored in a shareable manner that can be exchanged between computer systems, websites, databases and third-party applications

Z

zooxanthellae: algae that live in coral tissues

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