Good Science 7

Second Edition

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Warning: It is recommended that Aboriginal and Torres Strait Islander Peoples exercise caution when viewing this publication as it may contain images of deceased persons.

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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Contents

SCIENCE HOW-TO

Learning Ladder for Victoria Year 7

Steps in progression								
5	N/A	I can analyse how classification of living things changes over time	I can analyse how ecosystems respond to internal and external changes	I can analyse situations that affect the properties and behaviours of substances	I can discuss examples of separation techniques used in society	I can evaluate processes of resource extraction and energy production	I can analyse scenarios where celestial phenomena impact society	I can analyse how simple machines alter the direction and magnitude of forces
4	N/A	I can compare and contrast the structural features of a variety of organisms	I can interpret and predict the effects of environmental changes on ecosystems	I can compare the behaviours of substances in different states	I can select and apply techniques to separate substances in mixtures	I can compare the benefits and risks of obtaining and using resources	I can compare and contrast historical and contemporary understandings of celestial phenomena	I can predict how an object's motion is impacted when forces are applied
3	N/A	I can explain how biological diversity is ordered and organised	I can represent flows of matter and energy in ecosystems	I can use the particle model to explain the properties of substances	I can explain how mixtures can be separated based on the properties of their components	I can explain the importance of using resources sustainably	I can model the Earth–Sun–Moon cyclic changes to explain the observable changes on Earth	I can represent and explain the effects of forces acting on objects
2	N/A	I can classify organisms using classification tools	I can describe relationships between a variety of organisms	I can describe the arrangement and motion of particles in each state	I can describe the composition of different types of mixtures	I can distinguish between renewable and non-renewable resources	I can describe observable changes on Earth caused by celestial bodies	I can describe how forces can be used for different purposes
1	N/A	I can identify observable features of living things	I can identify features of an ecosystem	I can identify states of matter	I can distinguish between pure substances and mixtures	I can list Earth's resources	I can identify the key features of our solar system	I can identify forces acting on objects
	Introduction to science	**Biological science: Classification**	**Biological science: Ecosystems**	**Chemical science: Theories of matter**	**Chemical science: Mixtures**	**Earth and space science: Earth's resources**	**Earth and space science: Earth, the Sun and the Moon**	**Physical science: Forces and simple machines**
	VC2.0 Content description codes →	VC2S8U01	VC2S8U04	VC2S8U05	VC2S8U06	VC2S8U09	VC2S8U12	VC2S8U14 VC2S8U13

Science understanding

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

Year 7 curriculum correlation grid

CHAPTERS →	1.0 Introduction to science	2.0 Classification
Science understanding		
Classification **VC2S8U01** there are similarities and differences within and between groups of organisms living on Earth; the development and use of classification tools, including dichotomous keys, help order and organise human understanding of the diversity of life		✓
Ecosystems **VC2S8U04** matter and energy flow through ecosystems and can be represented using models, including food webs and food pyramids; populations will be affected by changing biotic and abiotic factors in an ecosystem including habitat loss, climate change, seasonal migration and introduction or removal of species		
Theories of matter **VC2S8U05** the particle and kinetic theories of matter can be used to describe the arrangement and motion of particles in a substance, including the attraction between particles, and to explain the properties and behaviour of substances, including melting point, boiling point, density, compressibility, gas pressure, viscosity, diffusion, sublimation, and expansion and contraction		
Mixtures **VC2S8U06** matter can be classified as pure substances such as elements and compounds or impure substances such as mixtures (including solutions), and can be modelled using the particle model; mixtures may have a uniform (homogeneous) or non-uniform (heterogeneous) composition and can be separated based on the properties of their components using techniques including filtration, decantation, evaporation, crystallisation, magnetic separation, distillation and chromatography		
Earth's resources **VC2S8U09** the sustainable use of Earth's resources is influenced by whether the resources are renewable or non-renewable; the processes involved in resource extraction and energy production come with both benefits and risks to sustainability		
Earth, the Sun and the Moon **VC2S8U12** cyclic changes in the relative positions of Earth, the Sun and the Moon can be modelled to show how these cycles cause eclipses and influence predictable phenomena on Earth, including seasons and tides		
Forces and simple machines **VC2S8U14** balanced and unbalanced forces acting on objects, including gravitational force, may be investigated and represented using force diagrams; changes in an object's motion can be related to its mass and the magnitude and direction of the forces acting on it **VC2S8U13** simple machines, including the lever, inclined plane, wedge, pulley, screw, and wheel and axle, alter the direction and magnitude of forces		

3.0 Ecosystems	4.0 Theories of matter	5.0 Mixtures	6.0 Earth’s resources	7.0 Earth, the Sun and the Moon	8.0 Forces and simple machines
✓					
	✓				
		✓			
			✓		
				✓	
					✓ ✓

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

3.0 Ecosystems	4.0 Theories of matter	5.0 Mixtures	6.0 Earth's resources	7.0 Earth, the Sun and the Moon	8.0 Forces and simple machines
✓	✓	✓	✓	✓	✓
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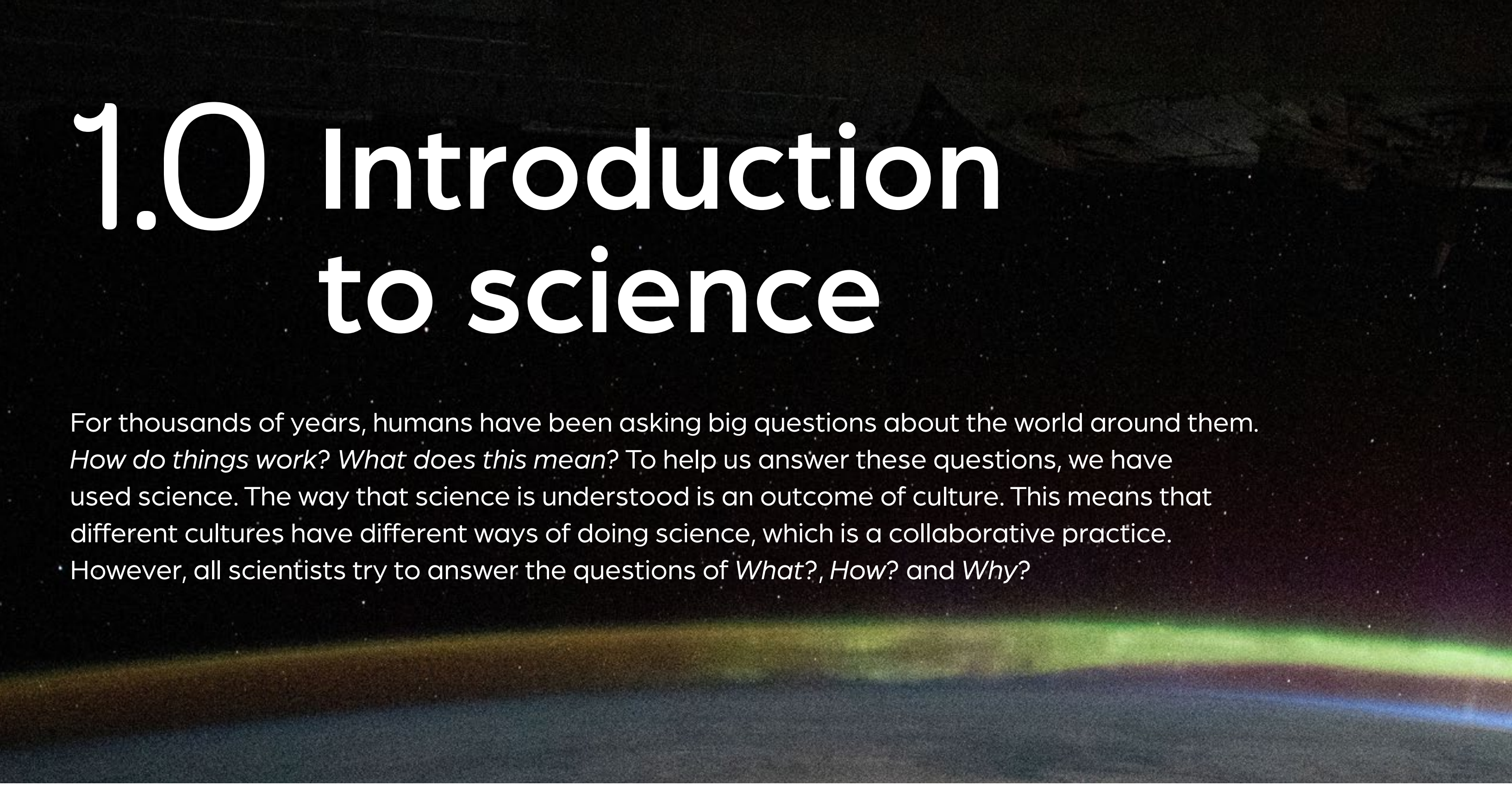


1.0 Introduction to science

For thousands of years, humans have been asking big questions about the world around them. *How do things work? What does this mean?* To help us answer these questions, we have used science. The way that science is understood is an outcome of culture. This means that different cultures have different ways of doing science, which is a collaborative practice. However, all scientists try to answer the questions of *What?*, *How?* and *Why?*

Learning Ladder

The Learning Ladder in Chapter 1 maps the Science as a Human Endeavour and selected Science Inquiry strands that will be covered. Each ladder has five levels of progression, called steps. To climb the ladders, you need to develop fluency at each step. This will help you develop the ability to complete tasks that are more complex.

Steps in progression	Nature and development of science	Use and influence of science
5	I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations
4	I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues
3	I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances
2	I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society
1	I can recognise scientific problems and solutions	I can identify socio-scientific issues

Science as a human endeavour

Figure 1.1: The Aurora Australis, or southern lights, which have been visible from south-eastern Australia for millennia, can now be studied from space using technological advances such as spacecraft, satellites and telescopes.

Steps in progression	Questioning and predicting	Planning and conducting	Communicating
5	I can evaluate investigation questions and predictions for scientific validity	I can design and conduct reproducible investigations that consider safety, ethical and procedural factors	I can communicate scientific findings and arguments for specific purposes to specific audiences
4	I can develop a hypothesis that predicts the relationship between investigation variables	I can generate and record data with precision, using digital tools as appropriate	I can use digital technologies to organise and communicate data and information
3	I can construct questions and predictions to investigate scientific problems	I can distinguish between variables to be changed, measured and controlled in an investigation	I can prepare a variety of representations to communicate ideas and findings
2	I can make simple predictions based on what I know and observe	I can describe ways to minimise risks for a range of investigations	I can select appropriate formats to communicate ideas and findings
1	I can recognise questions that can be investigated scientifically	I can identify and select appropriate equipment for scientific investigations	I can identify scientific terminology used to communicate information

Science inquiry

1·1 ▸ What is science?

Since humans evolved as a species, people have been making **observations** of natural events and using these observations to improve humans' knowledge and understanding of the universe.

Learning intention

At the end of this lesson, I will understand what science is and how it is practised by Western and First Nations scientists.

Key terms

Biological Sciences: the science of living things

branch: a type of science, such as biology or chemistry

Chemical Sciences: the science of chemicals and matter

collaboration: working cooperatively with other people to complete a task or solve a problem

Country: the physical environment with which a particular Aboriginal and Torres Strait Islander Peoples group has a deep and reciprocal relationship. One both owns and is owned by one's Country, which includes lands, waters and sky.

culture: a shared system of customs, habits, beliefs/spirituality, social organisation and ways of life that characterise different groups and communities

Earth and Space Sciences: the study of Earth's dynamic structure and Earth's place in the universe

observation: noticing something you can see, touch, smell, hear or taste, and know to be true

phenomenon (plural **phenomena**): an observable fact or event

Physical Sciences: the science of matter and energy

Science is the study of the universe

Science is the study of the universe and everything in it. The word 'science' comes from the Latin word *scientia*, which means to know or find out. This meaning links to the purpose of science, which is to build knowledge and understanding of the world (Earth) and the universe (everything: all of time and space and everything in it).

To do this, scientists work through a series of inquiry skills, which are:

- questioning and predicting
- planning and conducting
- processing, modelling and analysing
- evaluating
- communicating.

Using these skills, scientists can attempt to answer the big questions from the world around them. This often requires **collaboration** between people from different cultures who work across different specialist areas or **branches** of science. These branches are **Biological Sciences** (the science of living things), **Chemical Sciences** (the science of chemicals and matter), **Earth and Space Sciences** (the study of Earth's dynamic structure and Earth's place in the universe) and **Physical Sciences** (the science of matter and energy). The branches are called sciences because they can be further broken down into more specialised areas of science. For example, the Biological Sciences branch includes Ecology (the study of relationships between living things and their environment) and Zoology (the study of animals), while the Earth and Space Sciences branch includes Geology (the study of Earth and what it is made of) and Astronomy (the study of the universe and the objects that naturally exist in space).

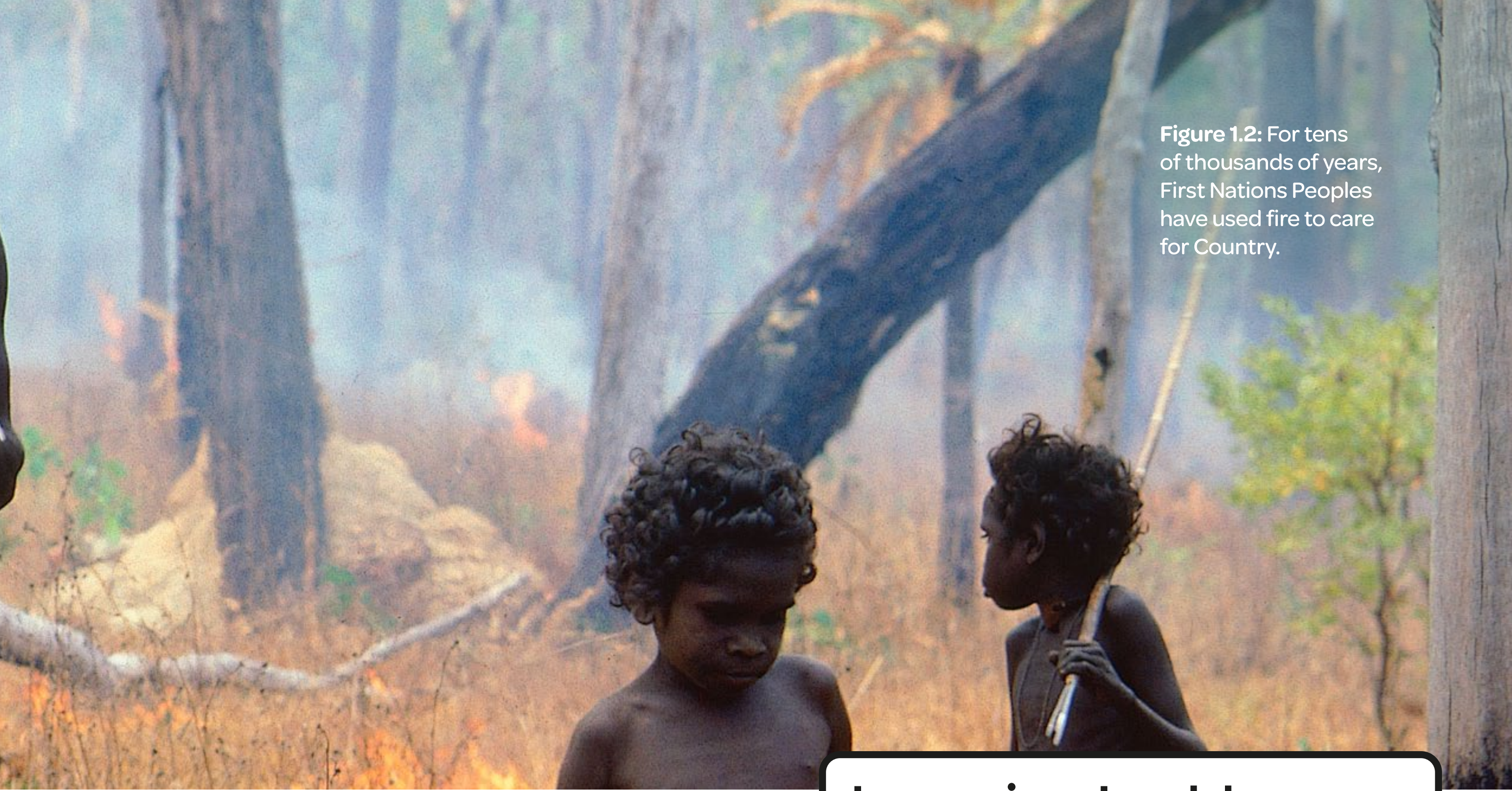


Figure 1.2: For tens of thousands of years, First Nations Peoples have used fire to care for Country.

Science is a product of **culture**, which is a lens through which we see the world. By practising science, we increase our knowledge. This allows us to solve problems, while also enhancing our way of life and caring for the environment.

First Nations and Western science have similarities

First Nations science and Western science are similar in many ways. Regardless of the science they practise, scientists observe natural **phenomena**, come up with explanations of these events and conduct experiments to test these ideas.

The purpose of science for all scientists is also similar: to increase their understanding of the world. First Nations Peoples also use this knowledge to care for **Country**. This sense of responsibility for managing the land, water, animals and plants is critical to Aboriginal and Torres Strait Islander Peoples' health and wellbeing.

The diverse range of activities involved in caring for Country requires First Nations Peoples to have a detailed understanding and knowledge of many branches of science, including those areas related to fire, animals, plants and the weather. This knowledge has been developed and passed down over thousands of years and is a form of **collaboration**.

Learning Ladder

Introduction to science

1. Identify the following:
   - a An inquiry skill that could be used to help understand the world
   - b Two branches of science
   - c The name given to the practice of working cooperatively to solve a problem
2. Describe how collaboration is related to First Nations Peoples' caring for Country.
3. Identify a similarity between First Nations and Western science.

Nature and development of science

1. Identify one environmental problem that science helps us to solve.
2. Describe why collaboration in caring for Country is important.

Communicating

p. 245

1. Identify and define any scientific terms used in this section that are not listed as key terms.
2. Construct an appropriate table to record the definitions of the terms identified in Question 1.

Success criteria

- I can explain what science is and how it is practised by Western and First Nations scientists.

1.2 ▸ The world's oldest scientists

Learning intention

At the end of this lesson, I will be able to describe the practice and communication of First Nations science.

Key terms

Ancestors: the people we are descended from

Elder: a First Nations person who is a recognised custodian of knowledge, who has permission to pass on that knowledge, and who has specific responsibilities to young people in a community

spirits: the supernatural beings that many First Nations Peoples believe exist; can be associated with particular places, objects and rituals; are often connected with Dreaming stories

Aboriginal and Torres Strait Islander Peoples have lived on the Australian continent and the adjacent islands for at least 65 000 years. This means that First Nations cultures are the oldest continuous cultures in the world. Since the beginning, Aboriginal and Torres Strait Islander Peoples have practised science.

First Nations science is practised in the natural environment

We can understand the practice of First Nations science by looking at the idea of Country. Aboriginal and Torres Strait Islander Peoples' idea of Country includes many different things: the physical land, the waterways, the sky, the languages spoken on that land, family, **Ancestors**, **spirits**, identity and culture. Country is the close, interwoven relationship between all these things and more. None of these elements can be separated or isolated from the others; they all rely on each other.

The practice of First Nations science is similar across First Nations cultures. Aboriginal and Torres Strait Islander science practice does not isolate things (such as animals and plants) and study them away from their natural surroundings in a laboratory. Observations are made and experiments are conducted in the natural environment.

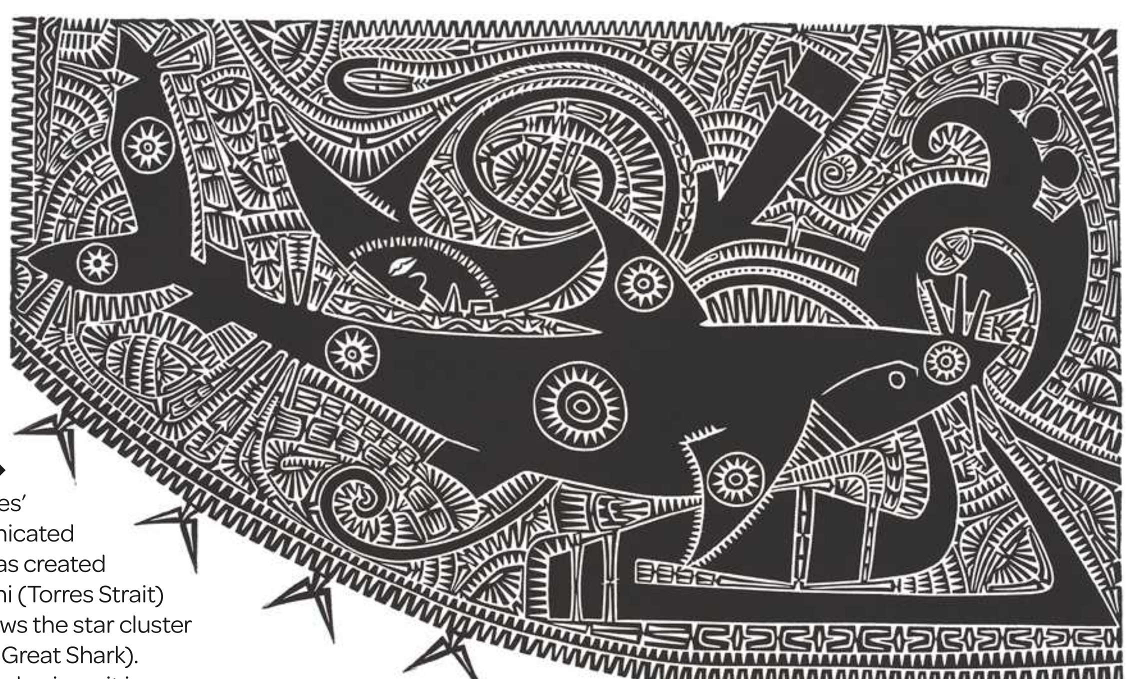


Figure 1.3: Aboriginal and Torres Strait Islander Peoples' knowledge can be communicated through art. This artwork was created by a Maluyligal and Wuthathi (Torres Strait) man, Brian Robinson. It shows the star cluster called Baidam Tithuyil (the Great Shark). When the shark touches the horizon, it is said to bring with it thunder and lightning and ushers in the monsoon season.

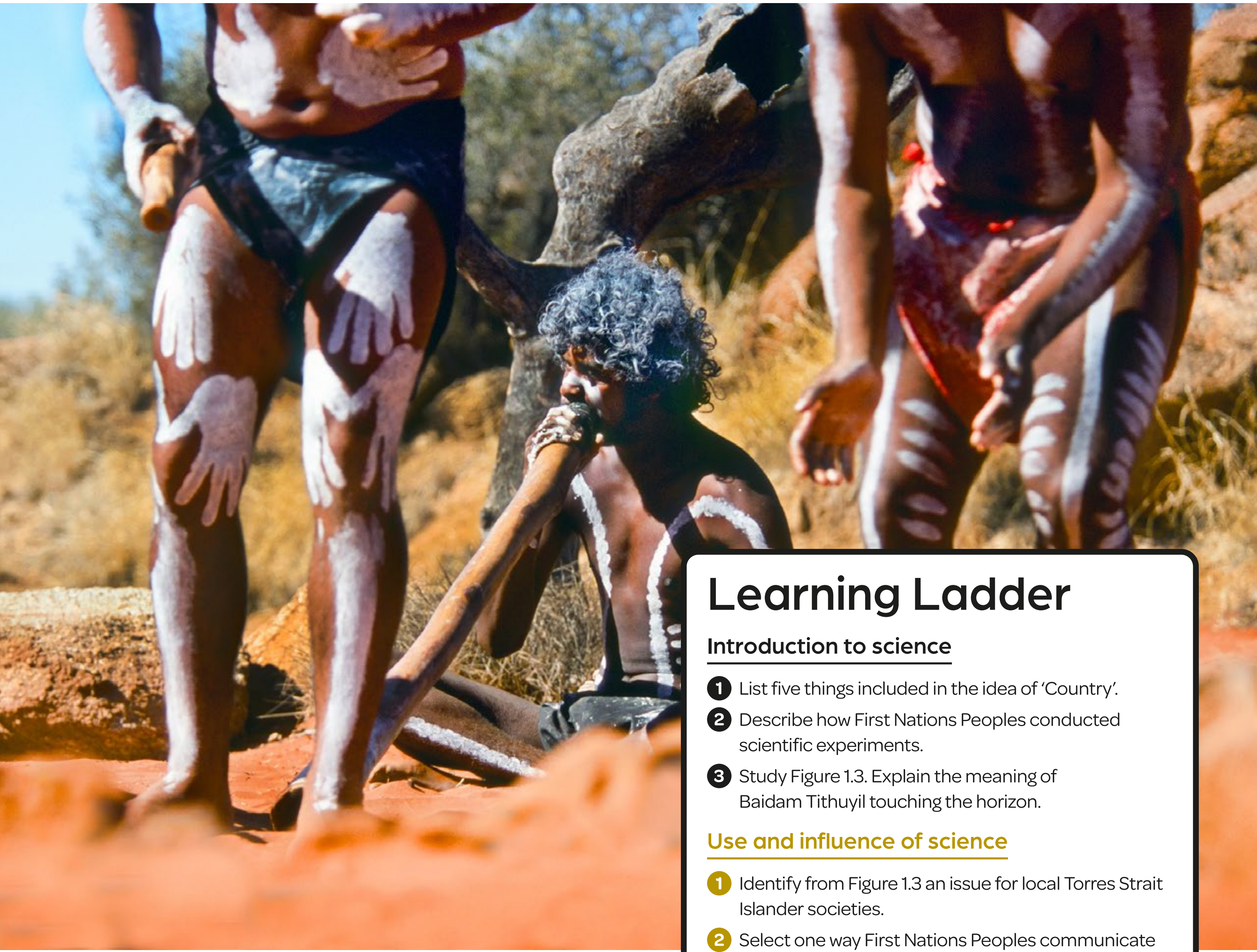


Figure 1.4: In Aboriginal and Torres Strait Islander cultures, scientific knowledge is often taught through dance.

First Nations scientific knowledge is communicated verbally and through art

Unlike the written reports favoured by Western scientists, the knowledge of First Nations science is passed on through oral traditions. The comprehensive scientific knowledge that First Nations Peoples have built – and continue to build – is passed from generation to generation through stories, song, dance and art (see Figure 1.3). Knowledge is often shared by the **Elders**.

Learning Ladder

Introduction to science

1. List five things included in the idea of 'Country'.
2. Describe how First Nations Peoples conducted scientific experiments.
3. Study Figure 1.3. Explain the meaning of Baidam Tithuyil touching the horizon.

Use and influence of science

1. Identify from Figure 1.3 an issue for local Torres Strait Islander societies.
2. Select one way First Nations Peoples communicate scientific ideas. Suggest how this might affect those societies differently from Western societies.
3. Propose how an understanding of Country impacts the ethical considerations of scientific advances.

Communicating p. 245

1. Identify and define any scientific words used in this section that are not listed as key terms.
2. Describe one way First Nations Peoples have shared scientific knowledge for millennia.
3. Examine Figure 1.3. Construct a diagram of the Baidam Tithuyil star cluster as it may appear in the night sky.

Success criteria

- I can describe how science is practised by First Nations Peoples.
- I can give examples of how scientific knowledge is communicated.

1.3 ▶ The branches of science

Learning intention

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

- describe the different branches of science
- give examples of how the different areas of scientific knowledge can be used in the real world.

Key terms

multidisciplinary: combining or involving more than one scientific branch of knowledge

transdisciplinary: collaboratively working across multiple branches to learn or solve problems

Western science can be divided into different areas of knowledge. These branches of science (Biological Sciences, Chemical Sciences, Earth and Space Sciences and Physical Sciences) can also be divided into more specialised sciences, as discussed below and in Section 1.1.

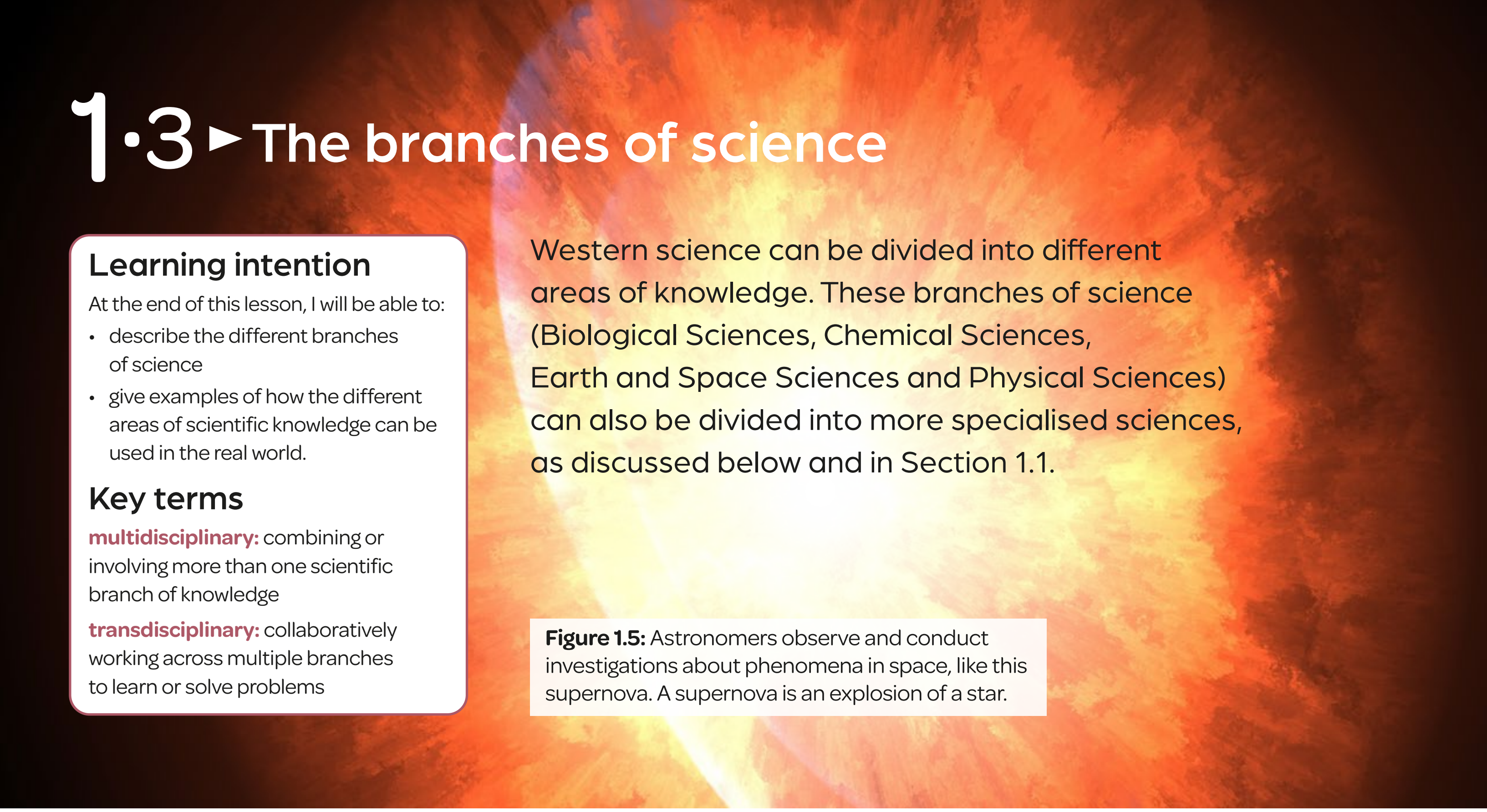


Figure 1.5: Astronomers observe and conduct investigations about phenomena in space, like this supernova. A supernova is an explosion of a star.

The four branches of Western science

Western science can be divided into four branches that are distinct but can overlap, depending on the problems that scientists are tackling.

- **Biological Sciences** are the sciences of living things. Biologists observe living things and investigate how they survive and thrive. They also solve problems relating to developing sustainable living practices. For example: *What features of a polar bear help it to survive in a cold environment?*
- **Chemical Sciences** are the study of chemicals and matter. Chemists observe and investigate how chemicals and matter are structured and can be used. They also solve problems relating to energy and medicine. For example: *What chemicals can treat deadly infectious diseases?*
- **Earth and Space Sciences** are the study of Earth and space. Geologists observe and investigate the structure of Earth, while astronomers observe and investigate things beyond Earth. They solve problems relating to Earth, space objects and travel. Two examples are:
  1. *How can we predict earthquakes?*
  2. *How does the Sun's gravity affect Earth's position in the solar system?*
- **Physical Sciences** are the study of matter and energy. Physicists observe and investigate how objects move and interact. They develop and test theories using modelling and other research to help solve problems in areas such as energy technologies and health care.

Within the four branches of science, there are many other sciences. For example, Ecology is a specialised biological science that focuses on how living things interact with their environments.

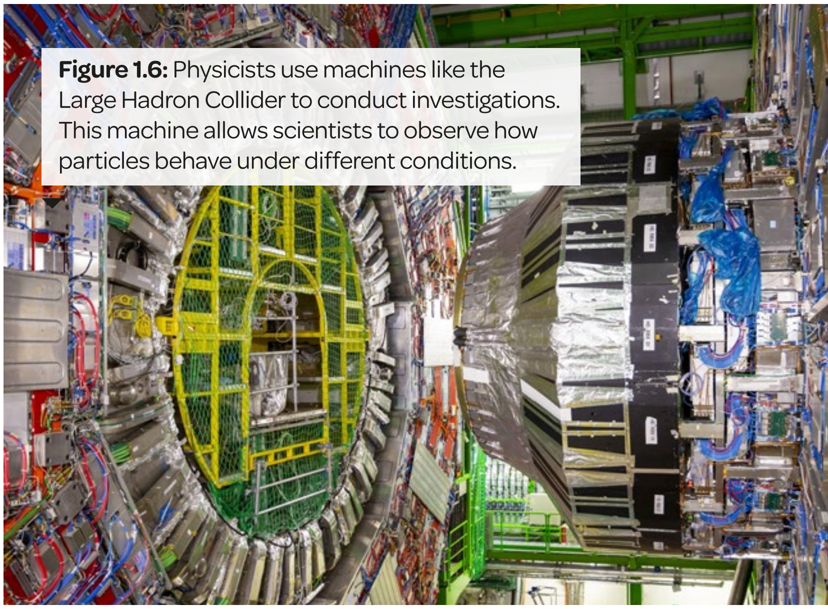


Figure 1.6: Physicists use machines like the Large Hadron Collider to conduct investigations. This machine allows scientists to observe how particles behave under different conditions.

Solving some problems needs knowledge from different areas of science

Many scientific problems are **multidisciplinary**; that is, they involve more than one branch of scientific knowledge in solving the problem. This means that science is **transdisciplinary**. For example, climate change is a worldwide problem for humans and other living things. To tackle this problem, scientists from different scientific disciplines are combining their knowledge and collaborating (see Table 1.1).

Figure 1.7: Ecologists use tools like carbon dioxide meters to measure the impact of climate change in different environments.

Table 1.1: The roles of ecologists, meteorologists and physicists in tackling the problem of climate change

Scientist	Role in tackling climate change
Ecologist	To observe and investigate how rising temperatures are affecting ecosystems
Meteorologist	To observe and investigate past and current weather patterns, and to predict future weather patterns
Physicist	To design and construct products that produce energy more sustainably

Learning Ladder

Introduction to science

1. Identify the branch of science that would be used to study:
   - **a** the features of an insect.
   - **b** a star in a new galaxy.
   - **c** how two chemicals interact.
2. Describe why it is important for science to be transdisciplinary.
3. Explain how scientists from different scientific disciplines are collaborating to solve the problem of climate change.

Nature and development of science

1. Identify a scientific problem that requires a multidisciplinary approach.
2. Describe why it is important to approach the problem you identified in Question 1 in this way.
3. Explain how the technologies in Figures 1.6 and 1.7 may have changed our scientific understanding of the world.

Questioning and predicting p. 222

1. From the following scientific questions, identify the one that would allow an ecologist to use the carbon dioxide meter shown in Figure 1.7 for an investigation.
   - **A** What gases are present in the atmosphere?
   - **B** What units are used to measure the amount of carbon dioxide gas in the air?
   - **C** Does the level of carbon dioxide present on Earth's surface affect the surrounding temperature?
2. Consider the example questions under the heading 'The four branches of Western science' at the start of this section. Select a question and predict the answer to it.
3. Construct a scientific question and prediction that could be used to test your answer to Question 2.

Success criteria

- I can describe the different branches of science.
- I can give examples of how the different branches of scientific knowledge can be used in the real world.

1.4 ▸ Science as a human endeavour

Learning intention

At the end of this lesson, I will be able to describe why science is a human endeavour.

Key terms

endeavour: to try to do something

evidence: facts and information that give reason to believe that something is true

experiment: a test done in order to learn something or to discover if something is true

metallurgy: the science of metals

Penicillin: a drug that fights bacterial infections

socio-scientific issue: an issue where science impacts on society, and may involve economic, environmental, ethical and social considerations

Science is the systematic study of the structure and behaviour of the physical and natural world through observation, experimentation and the testing of theories with evidence. It is all about people discovering and exploring new things, both individually and collaboratively, and building on the ideas of people who came before them to solve problems and deepen our understanding of our world. Without people, science cannot possibly exist; for this reason, it is a human endeavour. To '**endeavour**' means to strive or try to do something. Science as a human endeavour is as old as the existence of people and influences all aspects of our lives.

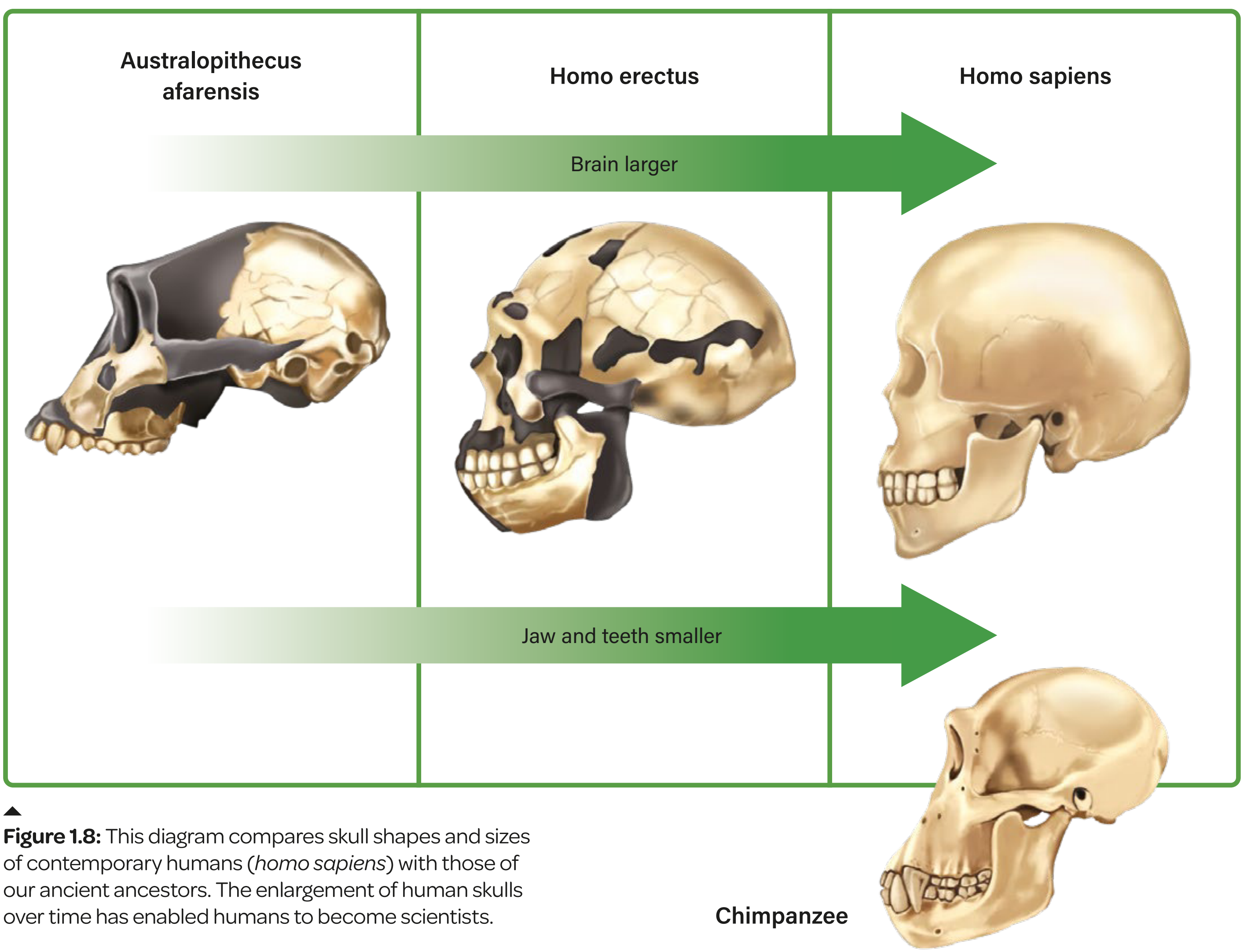


Figure 1.8: This diagram compares skull shapes and sizes of contemporary humans (*homo sapiens*) with those of our ancient ancestors. The enlargement of human skulls over time has enabled humans to become scientists.

Observation

Archaeological remains show that as humans evolved from our primate ancestors, our skulls changed dramatically (see Figure 1.8). They became much bigger as we evolved to have larger brains. This, in turn, allowed us to think about the world in new and interesting ways.

The earliest science was largely based on observation and **experimentation**. For example, if an individual was hungry, they might have observed what and how other animals were eating. Observation would also have provided people with insights into how to catch and hunt prey.

Not all observation is reliable, however. Consider Figure 1.9, which shows field mushrooms and death cap mushrooms. Field mushrooms are safe to eat; death cap mushrooms, which look very similar, are fatal if eaten. So, while observation is useful, experimentation is also important. By experimenting, people learnt which types of mushrooms were safe to eat and which ones were not.

Observation is useful for understanding 'what' is happening, but it does not explain 'why' something is happening.

Figure 1.9: Death cap and field mushrooms are very similar in appearance.

Figure 1.10: The durian has a prickly exterior and a very strong, unpleasant smell. It is only through endeavour and experimentation that people discovered it tastes delicious. It is now a staple food in many parts of the world.

Experimentation and evidence

Experiments help us to answer the 'why' questions by testing ideas and theories and gathering evidence. **Evidence** is facts or information that supports the theory that something is or is not true. Look at Figure 1.10. The appearance and smell of the durian suggest that it will not taste good. But at some point, someone decided to experiment and try it and discovered that it actually tastes great. That evidence has made it a very popular fruit. Scientific knowledge is not fixed: it is continually updated as we learn about the world around us.

Scientific experiments help us to gain scientific knowledge in a structured, evidence-based way. Experimentation and scientific research have led to amazing discoveries in all fields of science. The Australian researcher Howard Florey was one of three scientists in the 1940s who discovered **Penicillin**. The discovery of Penicillin has saved millions of lives around the world.

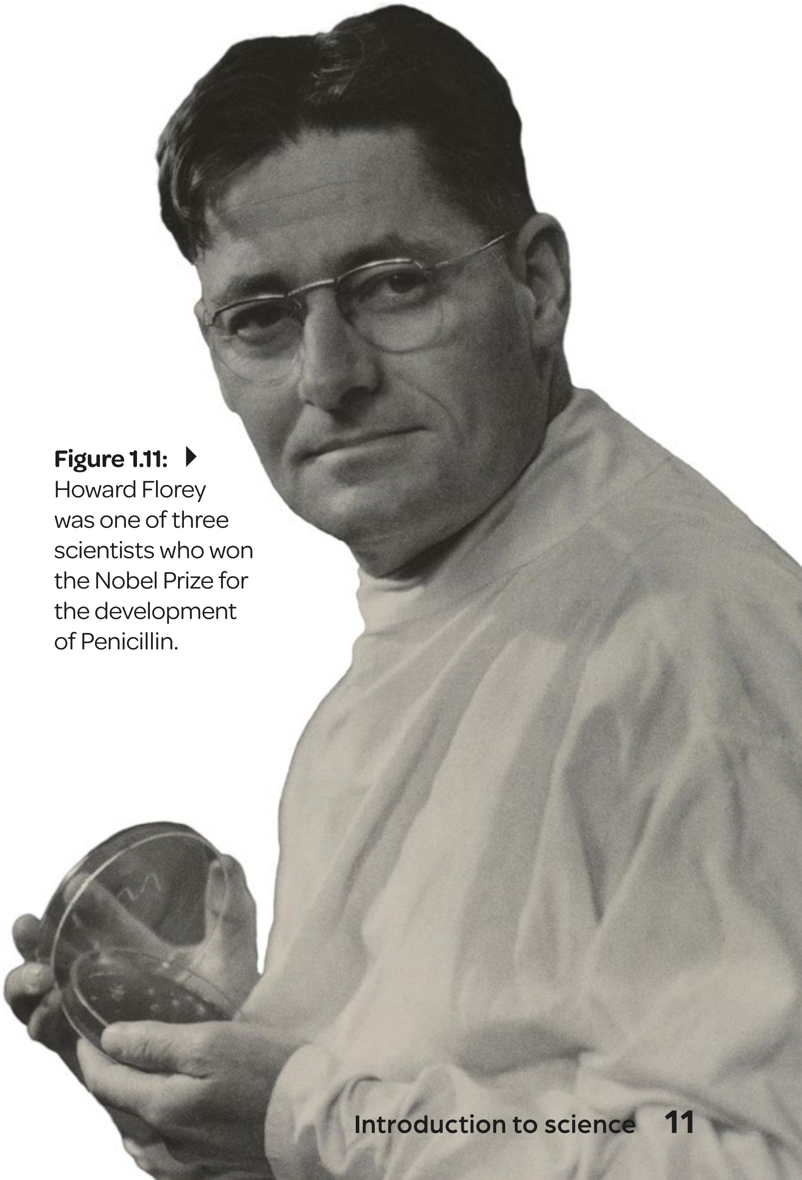


Figure 1.11: Howard Florey was one of three scientists who won the Nobel Prize for the development of Penicillin.

Good science

Science can help us answer important questions about our world. Right now, scientists are trying to understand climate change and global warming and the impacts they have on humans, animals and future generations. They are also trying to find ways to look after and preserve our fragile world. Climate change is a **socio-scientific issue**; that is, it is both scientific and social in nature. Scientific endeavour should reflect ethical, social and environmental considerations and help us to manage complex issues. Good science can make enormous contributions to individuals and to societies.

Figure 1.12: Arctic sea ice is rapidly diminishing due to climate change. Scientific studies show that the reduction of sea ice is making it harder for animals that live in these locations to find enough food to survive.

Scientific knowledge builds over time

Advances in science are often the result of contributions and developments over time. An example is **metallurgy**. Humans first started using metals around 7000 years ago. These metals were soft, like copper or gold, and would have been found on Earth's surface. They were then beaten into useful shapes at room temperature. About 4000 years ago, people discovered that certain metals could be heated and formed into shapes, and that heat sometimes changed the properties of those metals. The application of heat to metal transformed the creation of tools and weaponry. Nowadays, metallurgy is a highly sophisticated field of science that focuses on understanding how metals behave and finding ways to use them in sectors like aviation, engineering and electronics.

Figure 1.13: Large-scale operations like this steel mill use techniques developed over time to produce metal-based products that people use in their everyday lives.

Learning Ladder

Introduction to science

1. Identify two characteristics of the durian that meant people had to experiment to eat it.
2. Refer to Figure 1.9. Is observation always reliable in science?
3. Describe an observation an ancient human might have made to help them hunt animals.
4. Refer to Figure 1.8. Discuss the links between skull size and the development of science as a human endeavour.

Nature and development of science

1. Recall one scientific problem or solution included in this section.
2. Describe why collaboration is important in science.
3. Explain, with reference to metallurgy, how scientific knowledge can build over time.

Use and influence of science

1. Identify a socio-scientific issue discussed in this section.
2. Describe why the discovery of Penicillin was so important.
3. Explain some of the issues that need to be considered when discussing the impacts of climate change.

Communicating *p. 245*

1. Identify the two main questions that early science is focused on.
2. Create a presentation about why you should not eat wild mushrooms if you are not an expert in mushrooms.
3. Look at Figure 1.12. Write an article about how the decline in sea ice is affecting polar bears. See the Science how-to section, page 253, if you need help with writing your article.

Success criteria

- I can describe how science helps humans to understand and explain the world.

1·5 ▸ Key ideas in science

Learning intention

At the end of this lesson, I will be able to explain the key ideas that help scientists to make connections between scientific ideas and phenomena.

Key terms

form: what something is made up of

function: the way something works

quantify: to measure the size or amount of something

scale: the relationship between the sizes of two things

stable: remains the same; does not change

transfer: to move from one place to another

underpin: the starting point from which ideas develop

Western scientists use some key ideas to **underpin** their study of science. Understanding these key ideas can help us to make sense of the 'why?' and 'how?' of the scientific questions we ask and investigate.

The following key ideas can be incorporated when learning and applying concepts across the different branches and topics of science:

1 patterns, order and organisation
2 form and function
3 stability and change
4 scale and measurement
5 matter and energy
6 systems

1. There are often patterns to scientific phenomena

We can identify patterns in the world around us when we look at phenomena through a scientific lens. Scientists often use classification to organise different phenomena across the branches of science. For example, biologists organise living things into groups, and astronomers name objects in the universe (such as planets and galaxies) based on their features.

2. An object's form and function are related

Scientists are often able to describe the relationship between an object's **form** and its **function** by making observations about its appearance and role. For example, in ecosystems, the non-living and living components are directly related. As shown in Figure 1.14(a) and (b), rainy and tropical ecosystems support different plant life than ecosystems in hot, dry climates.

3. Some phenomena remain stable, while others change

Scientific investigations by different scientists help to determine the nature of different phenomena. Scientists have observed that some phenomena are **stable** over long periods of time, while others may change significantly. For example, Earth's distance from the Sun is stable. This means we can consistently rely on it as a source of energy. However, energy sources like coal and oil are not stable; they have been reduced as we have used them.

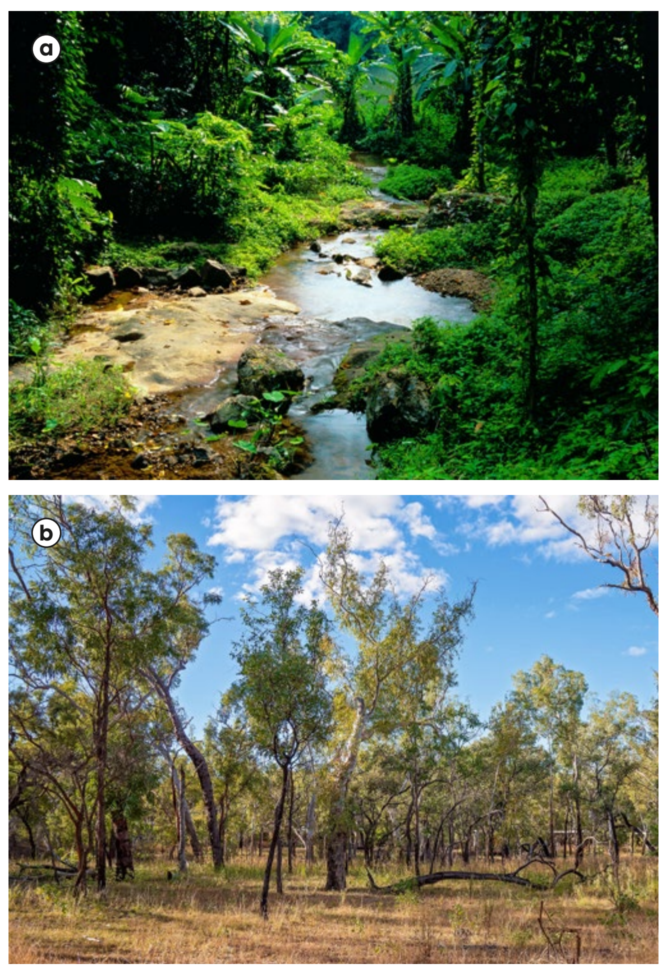


Figure 1.14: The plant life in an ecosystem varies based on ▸ non-living factors such as the water available. A tropical ecosystem (a) gets a lot more water than Australian bushland (b)!

4. Science is quantified through scale and measurement

Scientists use data to help **quantify** the world around us, which requires them to use different **scales**. For example, to quantify mixtures, we must understand objects at the small scale of particles and then apply this knowledge when looking at large-scale problems like oil spills. Other phenomena, like how the universe came into existence, occur on scales too large to quantify in our minds!

5. All phenomena involve the flow of matter and energy

All scientific phenomena rely on the **transfer** of matter and energy. Sometimes, this transfer can be observed directly, like when heat from the Sun is transferred to your skin. Other times, a heat transfer may affect the object at a particle level. More heat gives the particles of the object more energy. While we can sometimes observe this as a change of state (for example, when ice melts), objects are often transferring heat energy at a smaller level, which we need specific equipment to monitor.

Figure 1.15: While we can feel the Sun on our skin, we cannot directly observe how it is being transferred at a particle level.

6. Scientific phenomena can be organised in systems

Organising phenomena into systems allows us to understand, explain and predict why things happen in the world. Scientists look at the systems within individual objects and organisms, and at systems that control the relationships between objects and/or organisms. Forces are systems in action. When forces on an object are balanced, the object stays the same. However, when forces become unbalanced, the object will experience a change. For example, pushing the pedals on a stationary bike causes it to start moving. Systems can be extremely complex. For example, our solar system is a complex system held together by forces like gravity (Figure 1.16).

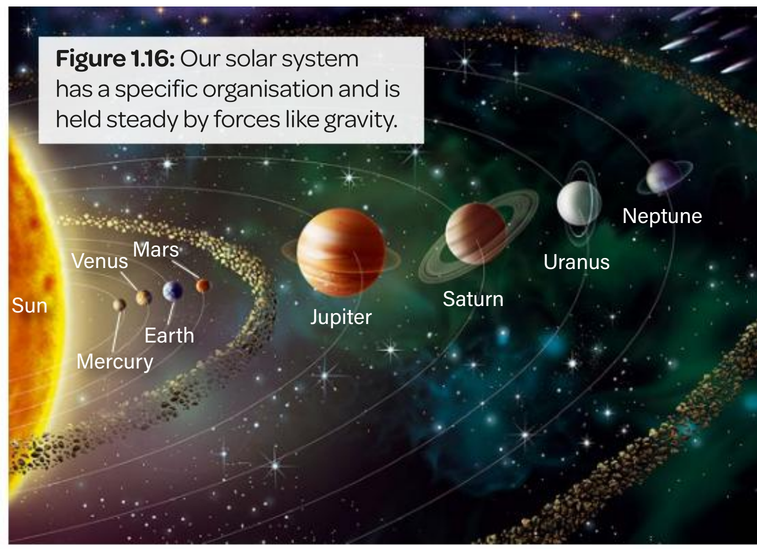


Figure 1.16: Our solar system has a specific organisation and is held steady by forces like gravity.

Learning Ladder

Introduction to science

1. Identify three key ideas that link to our solar system.
2. Describe, using an example, how an object's form can be related to its function.
3. Explain the importance of matter and energy to scientific phenomena.
4. Compare the scales that objects are looked at in chemistry (that is, particles) with those studied in astronomy (that is, the universe).

Use and influence of science

1. Identify an issue associated with the key idea of stability and change.
2. Describe, with reference to at least one key idea, how our knowledge of scientific phenomena can affect society.
3. Explain how scale and measurement may help us to understand environmental considerations when addressing problems.

Planning and conducting p. 226

1. Identify a piece of equipment that could be used to investigate the flow of heat energy. Refer to the Science how-to section on page 279.
2. Describe how scientists might minimise the risks associated with conducting investigations that involve looking at living things.

Success criteria

- I can explain how key ideas underpin our understanding of scientific phenomena.

1·6 ► Safety in science

Learning intention

At the end of this lesson, I will be able to describe basic safety practices that allow investigations to be safely conducted in a science laboratory.

Key terms

Bunsen burner: a piece of scientific equipment that produces a single open gas flame

hazard: something that can harm living things, objects or the environment

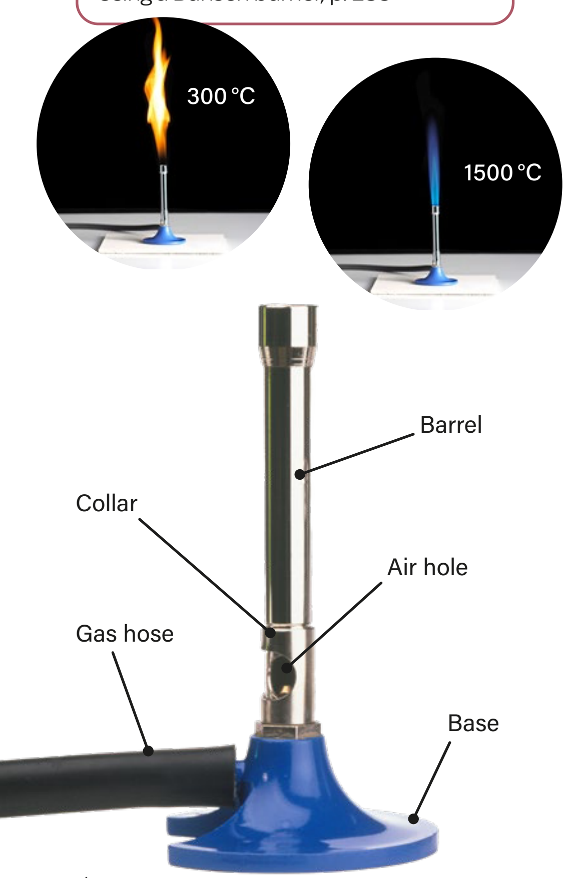
heating flame: the blue (very hot) flame of a Bunsen burner (approx. 1500 °C); used for heating substances

risk: the chance that a hazard will cause harm

safety flame: the orange (cooler) flame of a Bunsen burner (approx. 300 °C); used between heating substances

Investigation 1.6

Using a Bunsen burner, p. 285



▲ **Figure 1.17:** Bunsen burners are used to safely heat materials in a laboratory.

Safety is critical in science because all investigations carry some degree of risk. To reduce risk in first-hand investigations, plan your procedure and act in a safe manner in the laboratory. Also consider the safety of second-hand investigations to ensure the findings are scientifically valid.

Good safety practices control risk

Whenever you step into a laboratory to undertake an investigation, it is important to identify **hazards** and use good safety practices to control the **risk** of them causing harm. (See step 2 in 'Planning and conducting' and 'Using scientific equipment' in the Science how-to section on pages 227 and 277, respectively.)

It is important to use the safety equipment available in science laboratories, which includes:

- **safety glasses and face shields** to protect your eyes from fumes, particles and irritants
- **laboratory coats and aprons** to protect your clothes and body from chemical spills, flames and other hazards
- **gloves and hand protectors** to protect your hands when handling chemicals, biological materials and sharp objects
- **fire extinguishers**, which use dry chemicals (not water) to put out the flames if there is a fire
- **eye wash stations** if you get something in your eye; never rub your eye
- **laboratory hoods** to remove gases and fumes from the air (like an exhaust fan).

▲ **Figure 1.18:** All laboratories have safety rules that you must follow.

Figure 1.19: Wearing safety glasses, rubber gloves and a laboratory coat reduces risk when conducting investigations in the laboratory.

Bunsen burner safety

A **Bunsen burner** is a common piece of scientific equipment that is used for heating things in a laboratory (see Figure 1.17). It is crucial to know how to set up and safely use a Bunsen burner so as to avoid burns or gas leaks.

A Bunsen burner has two flames:

- The **safety flame** is an orange flame that reaches temperatures of about 300 °C.
- The **heating flame** is a blue flame that reaches temperatures of about 1500 °C.

Setting up and lighting a Bunsen burner

1. Time for the safety check! If you have long hair, tie it up. Put on your lab coat and safety glasses. Make sure you know the location of the fire extinguisher and fire blanket. Check the gas hose for any cracks, holes or tears.
2. Place a heatproof mat on the bench. Place the Bunsen burner on top of the mat. Connect the gas hose tightly to the gas tap.
3. Turn the collar of the Bunsen burner so the air hole is closed.
4. Ask your teacher to check the set-up of your Bunsen burner and provide any feedback.
5. A Bunsen burner is best lit by two people, one to light a match and one to turn on the gas tap.
6. Light a match and position it over the top of the barrel.
7. Ask your partner to turn on the gas tap.
8. Your Bunsen burner should now be lit with a yellow flame. Move away from the burner and extinguish the match. Turning the collar to open the air hole creates a blue flame.

Learning Ladder

Introduction to science

1. Identify a piece of safety equipment that could help you in the laboratory if you are working with flames.
2. Describe how to work with a partner to light a Bunsen burner safely.
3. Explain why it is important to ensure that second-hand investigations have considered safety issues.

Use and influence of science

1. Identify an issue with using unsafe practices in first-hand investigations.
2. Describe how our understanding of safety in first-hand investigations might help the wider community.
3. Explain how safety considerations could impact the development of new technologies, such as using radiation to treat cancer.

Planning and conducting p. 226

1. Identify three pieces of safety equipment that are required when working with a Bunsen burner.
2. Describe a safety precaution that needs to be taken when working with chemicals in the laboratory.
3. Read through the aim, materials and method from Investigation 1.6. For this investigation, identify the:
   - **a** independent (changed) variable.
   - **b** dependent (measured) variable.
   - **c** three controlled (kept consistent) variables.

Success criteria

- I can describe basic safety practices in a laboratory.

1·7 ▸ Ethics in science

Learning intention

At the end of this lesson, I will be able to describe ethical principles that ensure science is conducted safely, responsibly, and with respect for people, animals, culture and the environment.

Key terms

ethics: moral principles that impact how a person behaves; understandings of what is wrong or right

research proposal: a document setting out details of all aspects of a planned scientific investigation. Members of an ethics committee review it to ensure it conforms to the principles of good and safe science.

When conducting research, scientists must be guided by **ethics** – a set of moral principles that considers what is good for individuals, society and our planet. Scientific ethics guide how research is conducted and how scientific knowledge is applied in the world. Scientific investigations must follow ethical standards to ensure they are conducted safely, responsibly, and with respect for people, animals, culture and the environment.

Figure 1.20: Animals are no longer commonly used in school science experiments, since ethics approvals are now required in educational settings.

Ethics committees

An ethics committee ensures that the science that is conducted is good science; that is, it is practised safely, responsibly and with consideration for the wellbeing of all involved – both humans and animals. These committees consist of people who usually are not scientists and who often work in unrelated fields. They read **research proposals** from scientists to determine if they conform to ethics statements, guidelines and/or policies. If the committee decides that a proposal does not adequately address the ethics requirements, scientists can be required to revise and resubmit their proposal to ensure their experiment is ethical.

Ethical principles in scientific research

Balancing risks and benefits

Scientific experiments can involve risks, such as handling dangerous chemicals or diseases, or experimenting with medical treatments where the outcomes are unknown. Researchers must clearly communicate possible risks to participants and minimise unnecessary ones. Any possible harms must be carefully weighed against the possible benefits: if the potential benefit is too low and the risk is too high, it would be unethical to conduct the study.

Scientific validity

Ethical science requires scientists to clearly and honestly show their results and how they reached their conclusions, so that other scientists can review and repeat their work, with the same results. Scientists should design their investigations with a clear aim and research question and select suitable research methods. This means they must use the right equipment to measure the right observation and, importantly, ask the right questions. For example, they must ensure that some experiments occur in sterile conditions.

Free, prior and informed consent

All participants in an investigation must participate voluntarily, giving free, prior and informed consent. 'Free' means they agree of their own free will and can leave the experiment any time they wish. 'Prior' means they have been told about all parts of the experiment before it begins. 'Informed' means they understand all the potential risks of the experiment before they agree to participate. An investigation will not be ethical if all these forms of consent are not honoured.

Respectful treatment of human and animal participants

Some kinds of research cannot be done without human or animal subjects. In these cases, researchers must monitor the welfare of human and animal subjects and ensure they are always treated with respect. As a result of public debate around the use of animals in research, scientists take great care to minimise stress or harm to animal subjects and avoid using them altogether if possible.

Respectful treatment of culture

All science involves collaboration and building on the ideas of other people to learn new things: the best science comes from sharing perspectives and learning from each other in an ethical way. This means treating cultural sites, practices, beliefs, objects and scientific methods with respect.

Juukan Gorge is a sacred site on the lands of the Puutu Kunti Kurrama and Pinikura (PKKP) people in northern Western Australia. It contains multiple significant spiritual and ceremonial sites, such as a series of caves called the Juukan Gorge Rock Dwellings. The Juukan Gorge caves contain archaeological evidence that humans have lived continuously in the area for more than 46 000 years – including through Earth's last Ice Age! One of the most significant finds was a section of plaited human hair that is around 5000 years old. Using DNA testing, scientists conducted an investigation to show that the hair came from the direct ancestors of PKKP people living today!

In 2020, mining company Rio Tinto destroyed the Juukan Gorge Rock Dwellings by setting off explosives nearby, despite being aware of the site's spiritual and archaeological importance. This represented a profound loss for the PKKP people and caused worldwide outrage. Rio Tinto had permission from the Western Australian government to mine in the area, so their behaviour was legal – but was it ethical?

Figure 1.21: Gomeroi Traditional Custodians Uncle Steve Talbott and Aunty Dolly Talbott, Senator Lidia Thorpe, Minister Linda Burney, Josh Wilson MP, and GetUp's Larissa Baldwin with a petition on the steps of the Federal Parliament, calling for stronger heritage protection laws in the aftermath of Rio Tinto's destruction of Juukan Gorge.

Unethical science case study 1: Harlow's monkeys

In the 1950s, scientist Harry Harlow conducted an experiment where he separated baby monkeys from their mothers and tested whether they preferred a 'mother' monkey made of wire, or a 'mother' monkey made of cloth. He found the baby monkeys preferred the cloth mother, even if the wire mother was a source of food. The baby monkeys would visit the wire mother to eat and then return to the cloth mother. The experiment suggested that emotional and physical comfort were important to the baby's development, possibly just as important as food.

When Harlow published his findings, some researchers and members of the public disagreed that the scientific benefit of his studies justified the distress and anxiety the monkeys experienced. This public attention contributed to the development of modern ethics guidelines in research.

Figure 1.22: The baby monkeys preferred the soft, cloth 'mother', even if the wire 'mother' was a source of food. Did the findings of the experiment justify the distress the animals experienced?

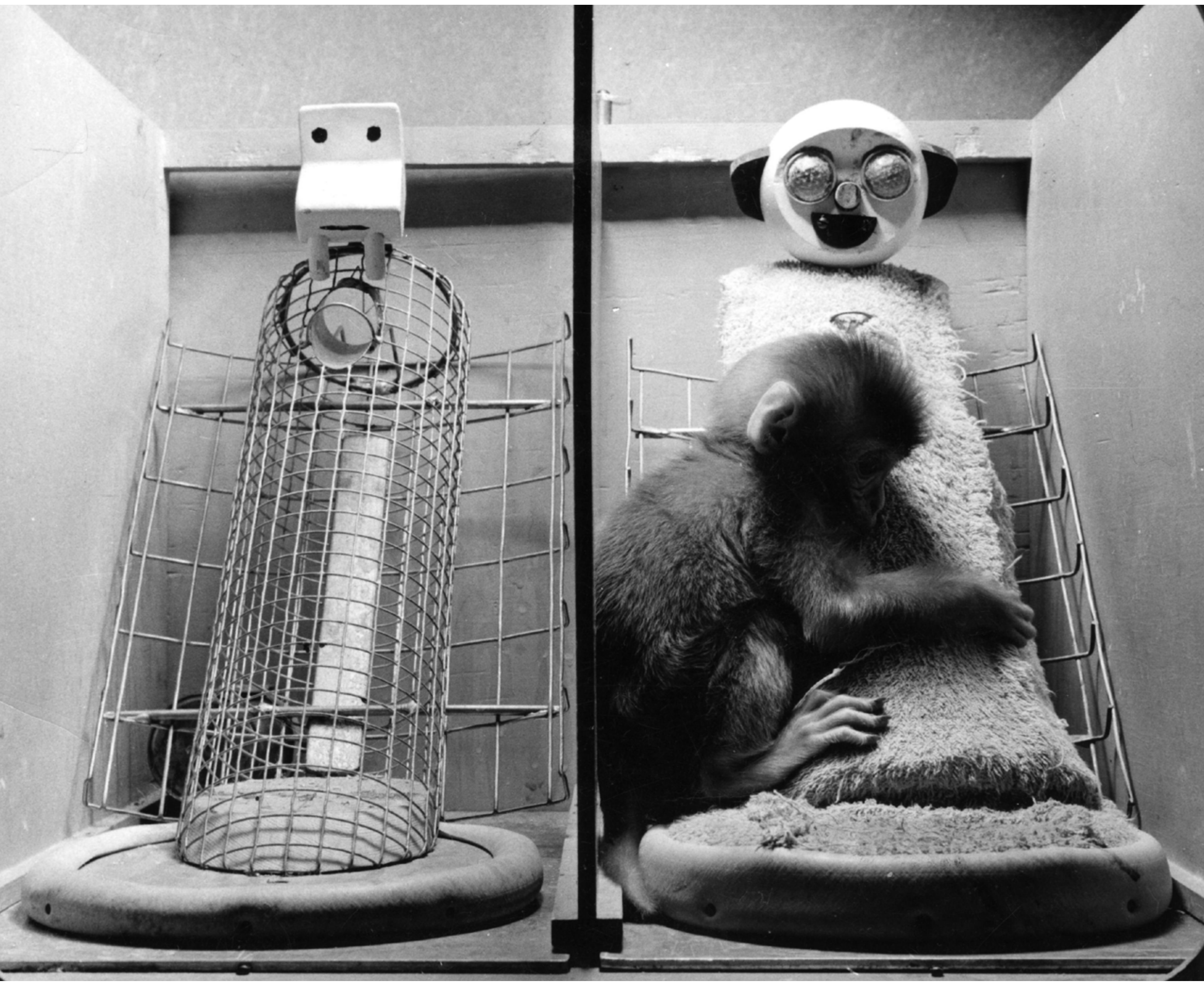


Figure 1.23: The 'Little Albert' experiment is an infamous example of unethical science.

Unethical science case study 2: the 'Little Albert' experiment

In 1920, a report was published in a psychology journal detailing an experiment where an infant, identified as 'Little Albert', was trained to associate real and toy animals with a frightening event such as a loud noise. This association meant that the infant showed fear when the animals were present, even without the loud noise. This experiment would now be considered unethical: for example, Albert could not give free, prior and informed consent, as he was an infant. Today, an ethics committee would review the research proposal to decide if the potential benefit of the experiment outweighed the risk of causing distress to the subject.

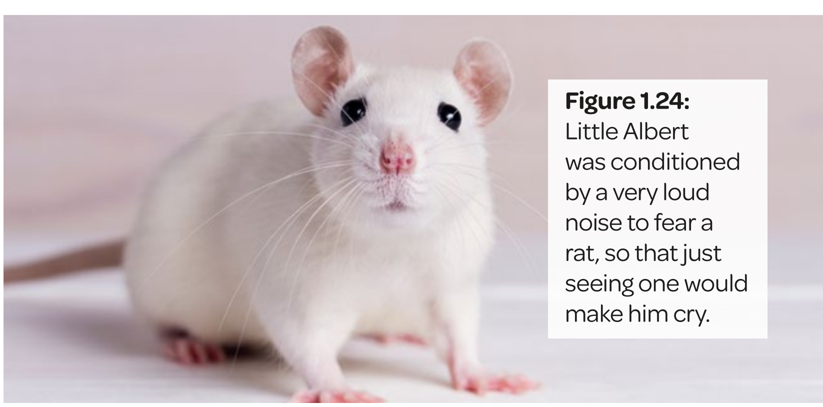


Figure 1.24: Little Albert was conditioned by a very loud noise to fear a rat, so that just seeing one would make him cry.

Learning Ladder

Introduction to science

1. Recall the ethical principles of scientific research.
2. Describe the purpose of an ethics committee.
3. Explain what each of the three terms of consent mean: *free*, *prior* and *informed*.

Use and influence of science

1. Consent is an important part of science because without it investigations may not be ____________, which poses a socio-scientific issue.
2. Describe why Harlow's experiments gained public attention.
3. Explain why the 'Little Albert' experiment was unethical, with reference to social impacts.

Communicating *p. 245*

1. Identify and define any scientific terms not included in the key terms.
2. Propose two ways you could communicate your perspective about unethical scientific practices.
3. Construct a letter to the Western Australian government about why the destruction of the Juukan Gorge Rock Dwellings may have been unethical.

Success criteria

- I can describe the principles of ethical science.
- I can explain case studies that involve unethical circumstances.

1.8 ▸ Observations and inferences

Learning intention

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

- describe how senses can be used to make observations
- explain how observations can be used to make inferences.

Key term

inference: a conclusion that is based on evidence and observations

Investigation 1.8

Comparing observations, p. 287

When conducting investigations, scientists make observations and draw inferences that explain natural phenomena.

Scientists observe using their senses

When conducting investigations, scientists can make observations using any of the five senses:

- **Sight:** Can a change be seen? For example, is a liquid bubbling or changing colour?
- **Touch:** Can a change be felt? For example, is a container warmer or colder?
- **Smell:** Is there a new scent? For example, can you smell something (like sulfur)?
- **Hearing:** Is there a new noise? For example, can you hear crackling or bubbling?
- **Taste:** Does a solution taste different? For example, does cake batter taste different before and after adding a specific ingredient? (Note: Do not taste chemical solutions in science unless you are explicitly instructed to do so by your teacher.)

Figure 1.25: By using your senses, you can make observations about what is occurring.

Inferences are educated guesses

Observations can be used to make inferences. **Inferences** are conclusions or educated guesses that are based on what has been observed and that explain what has happened.

For example, a friend comes to school on crutches, so you *infer* that they have had an accident. At lunchtime, your friend bites into a sandwich and makes a face, so you *infer* they do not like their lunch.

Figure 1.26: *Observation* (What do you see?): A drooping plant. *Inference:* The plant is getting too much or too little water.

Figure 1.27: *Observation* (What do you see?): A blackened landscape. *Inference:* There has been a bushfire in this area.

Table 1.2: A sample investigation, with observations and inferences

Investigation set-up	Observation	Inference
100 mL of cold water is in a beaker over the blue flame of a Bunsen burner.	After a certain amount of time, the water starts to bubble and steam forms.	The flame from the Bunsen burner is causing a change in the temperature of the water.
200 mL of cold water is in a beaker over the blue flame of a Bunsen burner.	After a longer amount of time, the water starts to bubble and steam forms.	The flame from the Bunsen burner is increasing the temperature of the water, but with more water it seems to takes longer.
300 mL of cold water is in a beaker over the blue flame of a Bunsen burner.	After an even longer amount of time, the water starts to bubble and steam forms.	The flame from the Bunsen burner is increasing the temperature of the water, but as the amount of water increases, so too does the time required for it to heat up and boil.

Figure 1.28: Making observations can allow us to make inferences about the impact of volume on heating time for water. ▶

Learning Ladder

Introduction to science

1. Identify the branches of science that are relevant to heating water.
2. Describe how scientists work together to make observations during an investigation.
3. **a** Describe what you observe in Figure 1.28.
   b Infer what the flame is doing to the water.

Use and influence of science

1. Identify an issue with using the sense of taste in laboratory investigations.
2. Describe the impact of being able to make inferences on our understanding of scientific phenomena.
3. Explain the difference between an observation and an inference, with reference to the Figure 1.27 caption.
4. Discuss the response a local government might make after observing the landscape shown in Figure 1.27.

Communicating

p. 245

1. Identify and define three scientific terms used in this section that are not listed as key terms.
2. Describe a method for constructing and presenting a list of definitions for these key terms.
3. Construct your selected method of communication from Question 2. Be sure to write each definition in your own words.

Success criteria

- I can describe how to use my senses to make observations.
- I can use my observations to make inferences.

1.9 ▸ Using scientific equipment to make observations

Learning intention

At the end of this lesson, I will be able to describe the impact of using scientific equipment on the accuracy and precision of my observations.

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

data: facts and information collected for reference or analysis

precise: how specific or exact a measured value is

qualitative data: data with qualities or characteristics that can be observed and described

quantitative data: data that can be counted, measured or represented by numbers

repeatable: provides consistent results when repeated

Investigation 1.9

Using scientific equipment to make observations, p. 288

Figure 1.29: By using a thermometer, you can measure the temperature of liquids more precisely.

Making observations is an important part of investigations. From these observations, scientists draw inferences that explain natural phenomena. Observations that are made using only our senses lack **accuracy**, whereas observations made using scientific equipment are more accurate and reliable.

Measuring with equipment improves accuracy

During investigations, scientists make observations using any of the five senses: sight, touch, smell, sound and taste. They also use a variety of equipment to take **precise** measurements and to collect **data**, such as thermometers, digital scales and stopwatches.

Data can be quantitative or qualitative:

- **Quantitative data** relates to quantities (that is, numbers) and can include the number of something, volume, length, time, or anything that can be measured or counted.
- **Qualitative data** relates to the qualities of something and can be written descriptions and observations. Qualitative data lacks accuracy.

Figure 1.30: Scientists use equipment like microscopes to make observations.

Table 1.3: Making observations using the senses versus using measuring equipment

Investigation	Observation using the senses	Observation using measuring equipment
Heating water over a Bunsen burner	I can see that the water bubbles and produces steam when it gets hot.	I can use a thermometer to measure the temperature of the water. The water starts to bubble and produce steam when it reaches 100 °C.
Dissolving salt in cold water	I can see that a small spoonful of salt dissolves. I can see that a large spoonful of salt does not completely dissolve. I can see this because there are salt crystals at the bottom of the beaker.	I can use a digital scale to weigh accurate quantities of salt, so I can calculate the exact amount of salt that can be dissolved in the beaker of cold water.
Boiling different liquids	I can see that some liquids take longer to start bubbling than other liquids.	I can use a thermometer to measure the temperature of each liquid when it starts to boil. I can use a stopwatch to measure the exact amount of time it takes each liquid to start boiling.

In each of the investigations in Table 1.3, using measuring equipment enabled the scientist to translate the observations they made with their senses into precise measurements, making their data more accurate.

This accuracy improved the scientist's observations. Accurate observations are more credible, valid and **repeatable**, and are therefore more likely to be accepted by other scientists.

Figure 1.31: Athletes use equipment like digital stopwatches and sensors to precisely measure their run times.

Learning Ladder

Introduction to science

1. Identify when it is important to use scientific equipment to improve the accuracy of investigations.
2. Describe how making observations using measuring equipment can improve our understanding of scientific concepts (for example, the boiling points of different liquids).
3. Explain how two pieces of scientific equipment you have identified can help make your observations about the boiling point of water more precise.

Nature and development of science

1. Identify a problem with making observations solely with our senses.
2. Describe how collaborating with others may help to improve the accuracy of measurements when conducting an investigation.
3. Explain, using examples, how particular items of scientific equipment have assisted scientists to make improvements in the field of medicine.

Questioning and predicting

p. 222

1. From the following questions, select one that could be used to conduct the salt investigation in Table 1.3.
   A How much salt does cold water dissolve?
   B Does salt dissolve in cold water?
   C Does the temperature of the water affect the amount of salt that can be dissolved?
2. Predict what the answer to the question you selected would be.
3. Construct an appropriate scientific question that you could ask when completing Investigation 1.9.

Success criteria

- I can explain why it is important to use scientific equipment to make observations during investigations.

Summary

- The purpose of science is to build knowledge and understanding of the world around us.
- Scientific understanding is built by observation, experimentation and the use of inferences that lead to conclusions.
- Science cannot exist without people. As a human endeavour, science is as old as the existence of people and influences all aspects of our lives.

First Nations science uses traditional practices to observe and care for Country.

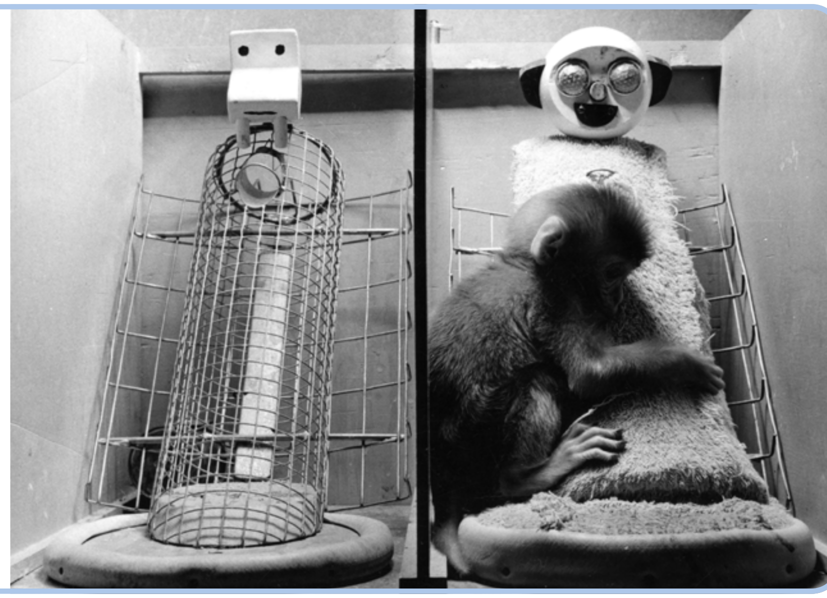
Scientists work together to build on each other's work. This means that collaboration in science is extremely important.

Western science includes four branches: Biological Sciences, Chemical Sciences, Earth and Space Sciences and Physical Sciences. The branches can be broken down into sub-branches; for example, Earth and Space Sciences can be broken down into Geology and Astronomy. The branches and sub-branches overlap and intersect.

Western science is underpinned by six key ideas that help us to understand all scientific phenomena. These key ideas are:

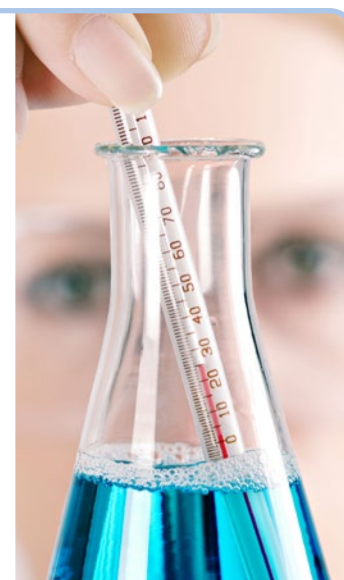
1. patterns, order and organisation
2. form and function
3. stability and change
4. scale and measurement
5. matter and energy
6. systems.

- All investigations have a degree of risk. When practising science, it is important to use good safety practices to minimise the risk of harm.
- All investigations, both first-hand and second-hand, must be conducted in a way that ensures their results are valid and trustworthy.
- All scientific investigations must follow ethical standards to ensure they are conducted safely, responsibly, and with respect for people, animals, culture and the environment.



Scientists make observations and draw inferences from them that explain natural phenomena.

- Observations made using measuring equipment are more precise than observations made using only our senses.
- Making sure our observations are precise helps us to obtain more accurate data during first-hand investigations.



2.0 Classification

Every single object on Earth can be sorted into one of two distinct categories: living or non-living. Living things are called organisms, which are made up of cells. Once something has been identified as a living thing, it is part of a hugely diverse group of organisms. To order and organise this diversity of life on Earth, scientists use classification, where they group things based on similar characteristics. These systems help scientists to organise the world around them so that we can better understand the patterns that exist among living things across the world.

Learning Ladder

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

Steps in progression	Science understanding: Biological science: Classification	Science as a human endeavour: Nature and development of science	Science as a human endeavour: Use and influence of science
5	I can analyse how classification of living things changes over time	I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations
4	I can compare and contrast the structural features of a variety of organisms	I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues
3	I can explain how biological diversity is ordered and organised	I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances
2	I can classify organisms using classification tools	I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society
1	I can identify observable features of living things	I can recognise scientific problems and solutions	I can identify socio-scientific issues

Figure 2.1: This quokka and all the plants in its habitat are living things, which can be classified into specific groups.

Steps in progression	Questioning and predicting	Planning and conducting	Communicating
5	I can evaluate investigation questions and predictions for scientific validity	I can design and conduct reproducible investigations that consider safety, ethical and procedural factors	I can communicate scientific findings and arguments for specific purposes to specific audiences
4	I can develop a hypothesis that predicts the relationship between investigation variables	I can generate and record data with precision, using digital tools as appropriate	I can use digital technologies to organise and communicate data and information
3	I can construct questions and predictions to investigate scientific problems	I can distinguish between variables to be changed, measured and controlled in an investigation	I can prepare a variety of representations to communicate ideas and findings
2	I can make simple predictions based on what I know and observe	I can describe ways to minimise risks for a range of investigations	I can select appropriate formats to communicate ideas and findings
1	I can recognise questions that can be investigated scientifically	I can identify and select appropriate equipment for scientific investigations	I can identify scientific terminology used to communicate information

Science inquiry

2·1 ▸ Characteristics of living things

Learning intention

At the end of this lesson, I will be able to describe the characteristics shared by all living things.

Key terms

carbon dioxide: a colourless and odourless gas containing carbon and oxygen that is produced during respiration

living thing: an organism that displays specific characteristics of being alive

mass: the amount of matter that a physical body contains

organism: an individual animal, plant or other living thing

respiration: a chemical reaction that converts glucose to energy

stimuli: changes in the environment that cause responses in living things

Key idea: Patterns, order and organisation

Figure 2.2: Frogs develop over time from tadpoles, which hatch from eggs.

Figure 2.3: Scientists can use microscopes to see the characteristics of living things.

There are millions of different organisms on Earth. How do scientists classify things as living or non-living?

Living things share three key characteristics

All **living things**:

- are made of cells
- are made of molecules containing carbon
- have biological characteristics in common, such as being able to grow, move, reproduce and respond to **stimuli**.

Living things have many other characteristics, and some organisms have the same features. Living things can also be very different from one another, such as dogs and octopuses!

Living things share seven biological characteristics

There are seven biological characteristics or features that **organisms** must have to be considered 'living' by scientists. These are:

- **Growth:** The organism gets bigger and develops over time. For example, frogs hatch from eggs as tadpoles and develop as they grow, and many plants grow from seeds.
- **Movement:** The organism can move part or all of itself. For example, humans can walk, and plants can move their leaves to face the sun.
- **Nutrition:** The organism takes in nutrients. For example, a bird eats insects, and plants absorb minerals from the soil.
- **Reproduction:** The organism can produce new offspring. This happens in many ways. Some organisms make identical copies of themselves, while others (like humans) require a mate.
- **Response to stimuli:** The organism can respond to changes in the environment. For example, kangaroos stay in shaded areas throughout the hottest parts of the day.
- **Respiration:** The organism can convert nutrients into energy. This happens in the organism's cells.
- **Waste removal:** The organism can get rid of waste products. In humans, this includes breathing out **carbon dioxide** gas and getting rid of urine and faeces.

If something does not have all seven of these characteristics, scientists will not classify it as living. For example, even though fire requires fuel to burn and it can spread, it does not respond to stimuli in the environment, so fire is classified as non-living.

We use scientific equipment to see the characteristics of living things

Some of the characteristics of living things can be hard to see. To see them, scientists use special equipment, such as:

- **Microscopes:** This technology allows scientists to see magnified images of different objects, including living things. This means that they can see the cells that make up living things. (See the Science how-to section on page 281.)
- **Digital scales:** Scientists use digital scales to measure the **mass** of living things. Increasing mass means the organism is growing!
- **Carbon dioxide probes:** These special probes measure the level of carbon dioxide in the air. If there is an increase in carbon dioxide in the air of an enclosed environment containing an animal, it proves that the animal is respiring.

Figure 2.4: Both bees and flowers have the seven biological characteristics of living things.

Learning Ladder

Classification

1. Identify two characteristics that all living things share.
2. Classify each of the following objects as living or non-living, based on their biological characteristics. Give a reason for your classification.
   a A fire **b** A wattle tree **c** Water
3. Identify an object that produces waste when you use it but which does not grow over time. Suggest whether scientists would classify your object as living or non-living. Explain your choice.
4. Discuss two characteristics that the bee and the flower in Figure 2.4 share.
5. Evaluate the following statement: 'Trees can't move from one spot to another, so they must not be living things'.

Nature and development of science

1. Identify one problem with classifying living things.
2. Describe why it is important for biologists and chemists to work together on classification.
3. Explain how using technologies such as microscopes and carbon dioxide probes can help scientists to classify objects as living organisms.

Questioning and predicting *p. 222*

1. From the following questions, identify the one a scientist could use in classifying a plant as a living thing.
   A How much carbon dioxide do plants produce?
   B Does the length of time a plant is in an enclosed environment affect the level of carbon dioxide in the air around it?
   C What do plants need in order to grow?
2. A frog is a living thing. If a scientist weighed a newly developed frog every day for a month using digital scales, predict the results they would expect to see.
3. Construct a question that would allow a scientist to conduct the investigation described in Question 2.

Key idea: Patterns, order and organisation

Identify five specimens from your school playground that have all seven characteristics of living things. Name the features that allow you to classify them as living. How are they related?

Success criteria

- I can describe the characteristics shared by all living things.

2.2 ▸ Classifying living things

Learning intention

At the end of this lesson, I will be able to describe what classification is and why it is useful.

Key terms

classification: the process of sorting things into groups or classes

species: a single, specific type of living thing

taxonomy: the science of classifying organisms

Investigation 2.2

Classifying items, p. 290

Key idea: Patterns, order and organisation

Classification is the process of sorting things into groups. Similar objects are placed in the same group. Classification plays an important role in ordering and organising the diversity of life on Earth.

Classification means sorting things into groups

Things can be classified for many different reasons, depending on who is doing the arranging, sorting or grouping.

Different classification systems exist in many areas in your daily life:

- In your school library, books are classified according to the Dewey Decimal Classification system, which is useful for finding both subjects and authors.
- We can sort items that can be recycled into paper, glass and plastic.
- Animals can be sorted into two groups: vertebrates (those with a backbone) and invertebrates (those without).

▲ **Figure 2.5:** Butterflies are classified by their colours, and by the shape of and patterns on their wings.

All scientists use classification

Biologists are scientists who study living things. The science of classifying organisms (sorting and arranging living things into groups) is called **taxonomy**. A biologist who specialises in classifying living things is called a taxonomist.

However, many scientists use classification:

- **Chemists** classify substances by their physical properties and their chemical reactions with other substances.
- **Geologists** classify rocks according to how they were formed and their mineral content, such as sedimentary, igneous and metamorphic.
- **Astronomers** classify objects in the universe by observing their properties, such as size, density and whether they give off light.
- **Meteorologists** classify different sections of the atmosphere surrounding Earth according to their temperature and how they affect the weather.

Classification is important

Classifying living things is important for many reasons:

- Classification helps biologists to work out whether different living things (for example, different **species**) are connected and the relationship between different organisms.
- Classification helps biologists to identify newly discovered organisms. New plants, insects, fish and bacteria are discovered every year.
- Using a classification system allows biologists from different countries to communicate with each other about their work. An Australian scientist may use different names for trees and plants than a Chinese, French or Indonesian scientist. However, if they use the same classification system, they can all easily identify an organism.
- Biologists can use classification to determine how species have evolved. This helps to show patterns and connections between related organisms.

Without classification, none of this is possible.

Figure 2.6: Is a cat closely related to a lion? They have similarities but are also very different. Classification helps biologists to identify how these two animals are related.

Figure 2.7: In our homes, we classify recyclable waste into different categories.

Learning Ladder

Classification

1. Identify two features you can use to group living things.
2. Classify the following organisms by size: alpaca, beetle, echidna, horse, iguana, leopard, platypus, wasp, zebra.
3. Explain why it is important for taxonomists to be able to classify organisms into groups.

Use and influence of science

1. Identify a communication issue that is solved using classification.
2. Describe how a classification system can help us to better understand living things.
3. Explain how the classifications used by meteorologists can help us to better protect the environment.

Planning and conducting p. 226

A student collected the following objects: scissors, five coloured pencils, a lead pencil, a red pen, a blue pen, a glue stick, an eraser, a pencil sharpener and a ruler.

1. Identify a piece of scientific equipment that the student could use to make observations of these objects. How should they use this equipment?
2. Describe two ways the student could minimise any risks associated with handling these objects.
3. Identify what the student is changing in this investigation (the independent variable) and what they are measuring (the dependent variable).
4. Propose how this investigation could be modified to collect precise quantitative data.
5. Construct a step-by-step method for your modified investigation from Question 4.

Key idea: Patterns, order and organisation

Identify five organisms that you can classify into one group. Describe two features that these organisms have in common.

Success criteria

- I can describe what classification is and why it is an important process.
- I can use classification to group organisms together.

2.3 ▸ The Linnaean classification system

Learning intention

At the end of this lesson, I will be able to describe and use the Linnaean system of classification.

Key term

naturalist: someone who studies nature and its history

Key idea: Patterns, order and organisation

It is important that scientists use the same system to classify living things. This enables them to compare their findings, share information and collaborate.

Scientists use the Linnaean system to classify species

A system for grouping living things was first proposed by Swedish **naturalist** Carolus Linnaeus in 1753. It is known as the Linnaean classification system and has been used by scientists to classify species since the 18th century.

The Linnaean system has eight levels

Linnaeus's system classifies organisms by levels called taxa, and each taxa is divided into groups. These groups are based mainly on cell and structural characteristics, and on how the organisms behave and reproduce.

At the highest level, these groups are huge: one group contains all the plant life on Earth. As we go down the levels, the groups become more specific.

At the top of the system, the most general classifications are domains and kingdoms. The characteristics used to separate these groups are based on cell structure. At the bottom of the system are genus and species. This is where we can identify individual types of organisms.

Figure 2.8: The Linnaean classification system has six kingdoms of life. These kingdoms are broad classification levels for all living things.

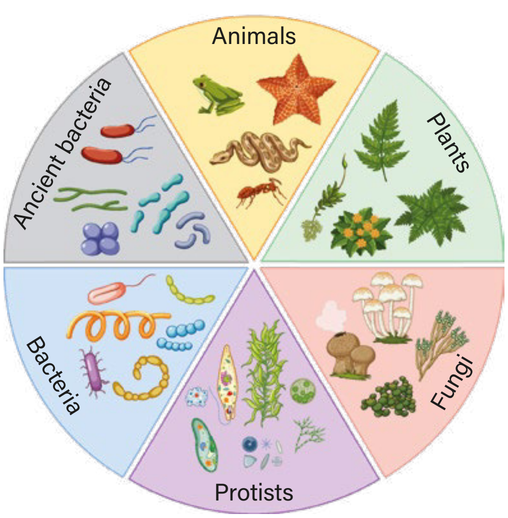


Figure 2.9: The classification of the brush-tailed rock wallaby, according to the Linnaean classification system.

Classification level	Classification for brush-tailed rock wallaby
Domain	Eukaryota (organisms with specialised cells)
Kingdom	Animalia (animals)
Phylum	Chordata (animals with a cord along their back)
Class	Mammalia (mammals) (animals with hair and live young)
Order	Marsupialia (marsupials) (animals with a pouch)
Family	Macropodidae (macropods) (animals with large hind legs and long tails, e.g. wallabies, kangaroos, pademelons)
Genus	*Petrogale* (rock wallabies)
Species	*Petrogale penicillata* (brush-tailed rock wallaby)

Very general ↔ Very specific

Figure 2.9 sets out how the brush-tailed rock wallaby is classified according to the Linnaean system.

Every species has a two-word name

All rock wallabies are part of the *Petrogale* genus, and the brush-tailed rock wallaby's species name is *penicillata*. This means that its full scientific name is *Petrogale penicillata*.

This naming is another important part of the Linnaean system: every species is given a two-word scientific name. These names are developed according to strict rules:

- The first word is the genus name and begins with a capital letter.
- The second word is the species name and begins with a lowercase letter.
- The name is shown in *italics* (or underlined when written by hand).

The words in these names are usually Latin or ancient Greek. Because these languages are no longer commonly used, they do not change over time as modern languages do. This is useful because the meanings stay the same. Even if scientists do not speak Latin, they can look up the words and find the same meaning each time.

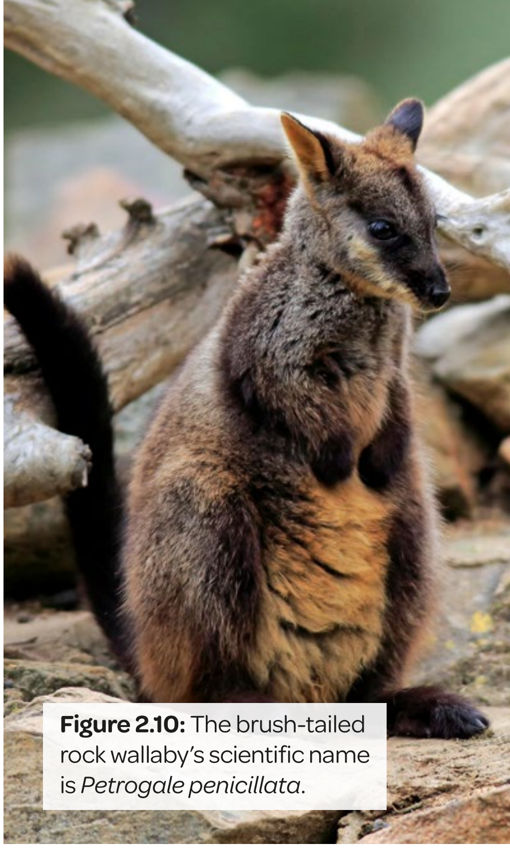


Figure 2.10: The brush-tailed rock wallaby's scientific name is *Petrogale penicillata*.

Learning Ladder

Classification

1. Identify three features of the brush-tailed rock wallaby that can help you to classify it.
2. Classify the domestic dog from the least to the most specific level:
   - Phylum: Chordata
   - Class: Mammalia
   - Kingdom: Animalia
   - Genus: *Canis*
   - Family: Canidae
   - Order: Carnivora
   - Domain: Eukaryota
   - Species: *Canis familiaris*
3. Explain how the different levels of classification help us to better understand the patterns among living things.
4. Compare the structural features of the plant and fungi illustrations in Figure 2.8.

Nature and development of science

1. Identify a solution that the Linnaean system of classification provides to scientists who are working with living things.
2. Describe how collaboration between past and present scientists has helped with classifying all the organisms we see around us today.

Questioning and predicting *p. 222*

1. From the following questions, identify the one that would be most appropriate for a scientist to use when classifying a newly discovered organism.
   A What other organisms does this one look like?
   B How big is this organism?
   C How do the features of this organism relate to other organisms that are similar to it?
2. Predict which of the following species the brush-tailed rock wallaby is most closely related to.
   A Red kangaroo **B** Platypus
   C Echidna **D** Grey wallaby
3. Construct a prediction that could be used to test your answer to Question 2.
4. Develop your prediction from Question 3 to ensure it considers the relationship between variables.
5. Swap hypotheses with a classmate, and evaluate each of them for scientific validity.

Key idea: Patterns, order and organisation

Classifying living things can reduce the risk of them harming humans. Using their common and scientific names, construct an infographic that classifies five Australian snakes according to how venomous they are.

Success criteria

- I can describe and use the Linnaean system of classification.

2.4 ▸ Classification keys

Learning intention

At the end of this lesson, I will be able to use a simple classification tool to categorise living things.

Key terms

classification key: a tool to help classify an organism by identifying important characteristics such as its features and behaviours

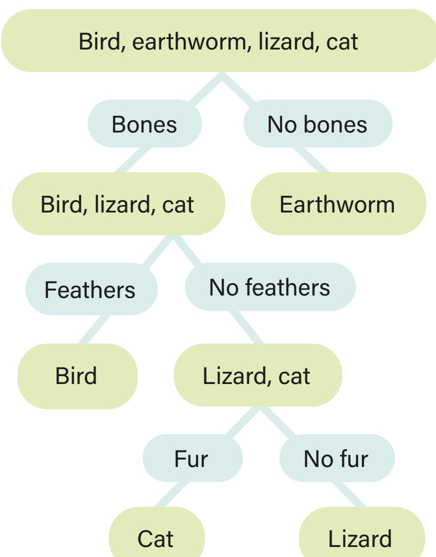
dichotomous: divided into two parts

Investigation 2.4

Classifying supermarket items, p. 291

Key idea: Patterns, order and organisation

▼ **Figure 2.11:** An example of a branching key that classifies the bird, earthworm, lizard and cat



Scientists use **classification keys** to help them categorise and identify living things. Classification keys may use pictures, words, numbers and instructions. There are different types of keys, including branching and dichotomous keys.

Some classification keys divide groups using branches

A common type of classification key is a branching key, which has two or more branches at each level to separate groups. As we move down the branches, we can identify characteristics until we determine the right organism. The branching key in Figure 2.11 shows how to identify a bird, earthworm, lizard and cat.

Dichotomous keys use questions or statements

Another type of key is a dichotomous key. '**Dichotomous**' means 'divided into two parts'. This classification key uses statements or questions with only two choices at each step. We can follow the directions until we identify the organism. For example, a dichotomous key for identifying a bird, an earthworm, a lizard and a cat might look like Figure 2.12.

▼ **Figure 2.12:** A dichotomous key that classifies the earthworm, bird, lizard and cat

1	a	Skeleton of bone	Go to step 2
	b	Does not contain bones	Earthworm
2	a	Covered in feathers	Bird
	b	Not covered in feathers	Go to step 3
3	a	Covered with dry scales	Lizard
	b	Covered with fur	Cat

When using a dichotomous key, we do not always go to the next numbered step. This is because keys can be used to divide many animals at once, meaning not all animals will be relevant to each step (see Figure 2.13).

▼ **Figure 2.13:** A dichotomous key that classifies the spider, scorpion, fly and dragonfly

1	a	4 pairs of legs	Go to step 2
	b	3 pairs of legs	Go to step 3
2	a	Fangs to inject venom	Spider
	b	Barbed stinger to inject venom	Scorpion
3	a	1 pair of wings	Fly
	b	2 pairs of wings	Dragonfly

Classification keys identify important characteristics

The most important part of designing a classification key is deciding which characteristics to include to identify organisms. The features chosen for a key depend on the organisms to be classified.

The first steps of a key should be easily observable features – for example, whether an organism has a backbone. When the classification becomes more specific, the key needs more detail – for example, whether an insect has spots on its wings.

The largest group of animals on Earth is the arthropods. 'Arthropoda' means 'jointed feet', and all arthropods have legs with joints as well as an exoskeleton (a rigid covering around the body). Table 2.1 shows the five classes (subgroups) of arthropod, and the physical characteristics of each.

Table 2.1: The five classes of arthropod

Class	Characteristics	Example(s)
Insects	▪ 3 body parts (head, thorax, abdomen) ▪ 6 legs (3 pairs) ▪ 0, 1 or 2 pairs of wings ▪ 1 pair of antennae 	Fly, mosquito, dragonfly 
Crustaceans	▪ 3 body parts (head, thorax, abdomen) ▪ 10 legs (5 pairs) ▪ No wings ▪ 2 pairs of antennae 	Crab, lobster, prawn
Arachnids	▪ 2 body parts (cephalothorax, abdomen) ▪ 8 legs (4 pairs [illegible] ▪ No wings ▪ No antennae 	Spider, tick, [illegible]pion
Centipedes	▪ Many body se[illegible] ▪ 1 pair of legs [illegible] ▪ Flat body cross-section ▪ No wings ▪ 1 pair of antennae	[illegible]ipede 
Millipedes	▪ Many body segments ▪ 2 pairs of legs on each segment ▪ Rounded body cross-section ▪ No wings ▪ 1 pair of antennae 	Millipede

Learning Ladder

Classification

1. Identify two features shared by the following:
   - **a** Australian funnel-web spider
   - **b** Dragonfly
   - **c** Blue swimmer crab
2. Describe some of the structural features of humans that could be used to help classify them.
3. You have discovered a new species of arthropod. It has 10 spiky legs, a head, a thorax and an abdomen, and it cannot fly. Using Table 2.1, suggest which class of arthropod it belongs to. Explain your choice.

Use and influence of science

1. Identify an issue that may occur when classifying arthropods.
2. Describe how our knowledge of classification keys can help us to better manage local environments.
3. Scientific advances have helped humans create new breeds of dogs. Construct a dichotomous key to organise 10 dog breeds you can identify. Suggest an ethical factor to consider when creating new breeds of dogs.

Planning and conducting *p. 226*

Read the aim, materials and method for Investigation 2.4 on page 291.

1. Identify three pieces of equipment used.
2. Identify a risk associated with this investigation. Describe the steps you would take to help minimise it.
3. For this investigation, identify the following:
   - **a** Independent (changed) variable
   - **b** Dependent (measured) variable
   - **c** Controlled (kept consistent) variables
4. Explain how you would precisely record your data.
5. Design a similar step-by step investigation for classifying organisms encountered on a class trip to the zoo.

Key idea: Patterns, order and organisation

Classification keys can help in organising organisms that exist in similar environments. Design a simple classification key to identify five organisms from a local habitat of your choosing.

Success criteria

- I can use a simple classification key to categorise living things.

2.5 ▸ Classifying animals

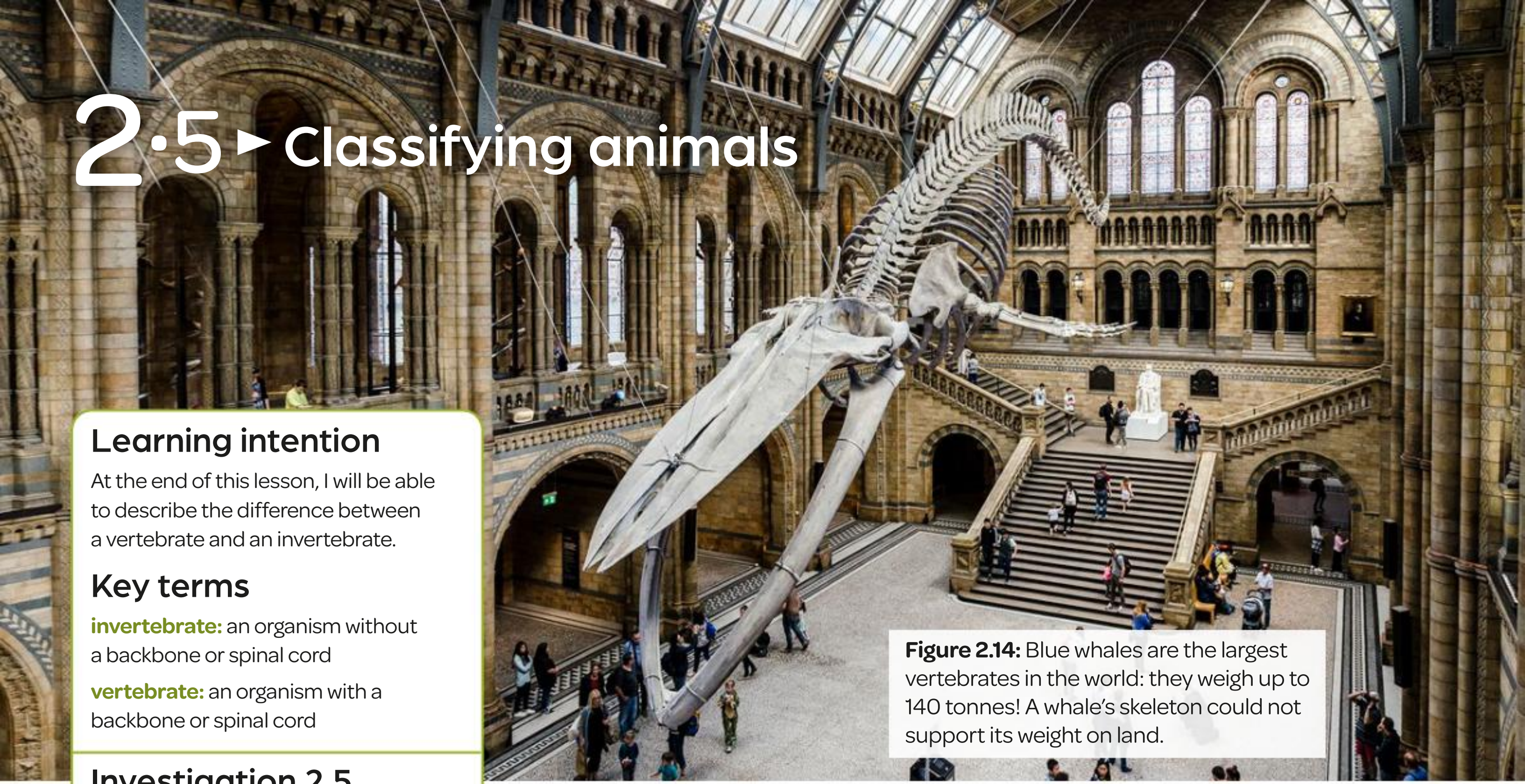


Figure 2.14: Blue whales are the largest vertebrates in the world: they weigh up to 140 tonnes! A whale's skeleton could not support its weight on land.

Learning intention

At the end of this lesson, I will be able to describe the difference between a vertebrate and an invertebrate.

Key terms

invertebrate: an organism without a backbone or spinal cord

vertebrate: an organism with a backbone or spinal cord

Investigation 2.5

Investigating features of marine animals, p. 292

Key idea: Patterns, order and organisation

From the largest whale to the smallest insect, there are more than 800 000 different animal species in the kingdom Animalia. The first question to consider when classifying animals is whether or not they have backbones.

Vertebrates are animals with backbones

Some animals – such as humans – have a backbone or spine, which is made up of oddly shaped bones called vertebrae. Animals with backbones are called **vertebrates**. In the Linnaean classification system, vertebrates are members of the phylum Chordata. All the animals in this group have a flexible nerve cord inside their backbone that sends information between all parts of the body.

Fossils show that vertebrates have existed for at least 518 million years. Over time, more and more vertebrate species have evolved. Today, there is a diverse range of animals with backbones.

Table 2.2: The five classes of the phylum Chordata

Class	Body covering	Temperature control	Reproduction	Structure for movement	Example
Fish	Slimy scales	Gains heat from surroundings	Lays eggs	Fins to move through water	Salmon
Amphibians	Naked skin	Gains heat from surroundings	Lays eggs in water	Young (tadpoles) have fins; adults have legs	Frog
Reptiles	Dry scales	Gains heat from surroundings	Lays leathery eggs	Legs for walking on land (except snakes)	Crocodile
Birds	Feathers and scales (on feet)	Produces own heat	Lays hard-shelled eggs	Legs for walking on land and wings for flying	Kookaburra
Mammals	Hair or fur	Produces own heat	Lays eggs	Legs with different shapes for walking, swimming or flying	Echidna
			Gives birth to underdeveloped young		Human
			Gives birth to fully developed young		Dog

Invertebrates are animals without backbones

The prefix 'in-' means 'not', so **invertebrate** means 'not a vertebrate'. These animals do not have backbones or any other bones.

There are many different phyla (groups) of invertebrates. They can be grouped by structural features. Most invertebrates have an exoskeleton, which is a rigid covering outside the body that is not made of bone. This supports the animal as it moves. Some invertebrates – such as worms – do not have an exoskeleton. These animals have internal structures that support them.

Table 2.3: Some of the many phyla (groups) of invertebrates

Phylum (group)	Characteristics	Example(s)
Cnidarians	Soft body with one opening	Anemone, coral, jellyfish
Annelids	Segmented worm, round cross-section, lives on land	Earthworm
Platyhelminths	Segmented worm, flat cross-section, lives in fresh water or in another organism	Tapeworm, planarian worm
Nematodes	Unsegmented worm, round cross-section, often lives in another organism	Round worm, heartworm
Poriferans	Collection of cells, some with hair-like structures, one opening	Sponge
Molluscs	Shelled animal	Snail, clam, oyster
Echinoderms	Body parts arranged around a central point, has many 'feet'	Sea star, sea urchin, brittle star
Arthropods	Jointed legs, exoskeleton, segmented body	Insect, prawn, spider

There are more species of invertebrates than vertebrates

Invertebrates account for around 95 per cent of all the species in the animal kingdom. There is also a large range of invertebrate species. These diverse animals can be sorted into many different groups.

Figure 2.15: All insects are invertebrates: instead of backbones, most have exoskeletons.

Learning Ladder

Classification

1. Identify the main difference between a vertebrate and an invertebrate.
2. Classify the following invertebrates into their correct phylum (group). Use Table 2.3 to help you.
   a Earthworm **b** Mussel (a shelled animal)
   c Snail **d** Lobster
3. Explain how you can tell if an organism is a vertebrate or an invertebrate just by looking at it.
4. Compare and contrast the features that provide vertebrates and invertebrates with structural support.
5. Many vertebrates from different classes and species have similar bone structures. Suggest how, over time, this may have changed the way vertebrates are classified.

Nature and development of science

1. Propose a problem that can be solved by a system that allows us to classify invertebrates.
2. Describe how collaboration between scientists assists in studying the bone structures of different vertebrates.
3. Explain how an organism's classification can be changed by new evidence about its structure and features.

Communicating *p. 245*

1. Identify three scientific terms used in this section that are not listed as key terms.
2. Construct an appropriate table to record the definitions of the terms identified in Question 1.
3. Use a digital platform to construct an infographic that compares the features of two classes of vertebrates.

Key idea: Patterns, order and organisation

Identify the five categories that vertebrates can be classified into according to the Linnaean system of classification. Classify three Australian vertebrates into more specific categories. Justify your classifications.

Success criteria

- I can describe the difference between a vertebrate and an invertebrate.
- I can give at least two examples of vertebrates and invertebrates.

2·6 ▸ Classifying plants

Learning intention

At the end of this lesson, I will be able to classify a variety of plants based on some of their features.

Key terms

angiosperm: a plant that produces seeds in fruit or flowers

bryophyte: a plant that does not contain vascular tissue

gymnosperm: a plant that produces seeds in cones

spore: a tiny part of some plants that is used to reproduce

structure: the construction and arrangement of tissues, parts or organs

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

tracheophyte: a plant that contains vascular tissue

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

Key idea: Patterns, order and organisation

Figure 2.16: Ferns reproduce using spores.

There are almost 400 000 plant species in the kingdom Plantae. The incredible variety of plants includes ferns, mosses and flowering plants. Like other organisms, plants can be classified by their **structure**.

Plants can be classified by their tissue

Plants can be grouped according to their type of **tissue**:

- Vascular plants (**tracheophytes**) have **vascular tissue**.
- Non-vascular plants (**bryophytes**) do not have vascular tissue.

Vascular tissue transports sugars, water and minerals through tiny tubes in the plant. It also supports the plant structurally. Vascular tissue works in a similar way to the bones and blood vessels of mammals.

Tracheophytes (vascular plants)

Most plants are tracheophytes (vascular plants), which are supported from inside and can grow very tall. Water moves from the soil into the roots, the stem and then the leaves. Glucose is made in the leaves, from where it travels to the rest of the plant to be used for energy or converted to starch and stored. Most vascular plants reproduce using seeds. These small grains with hard outer coatings contain the material plants need to reproduce.

Bryophytes (non-vascular plants)

Bryophytes do not have internal support, so they cannot grow very tall. Instead, they appear as soft coverings such as mosses and liverworts on surfaces like rocks and soil. Non-vascular plants do not have true roots or leaves. Bryophytes grow in areas where water is plentiful, such as next to rivers or waterfalls, or in rainforests.

Non-vascular plants reproduce using **spores**. These are small, round spheres on the underside of leaves. Spores fall to the ground and grow into heart-shaped plants that produce male and female cells. Spores need water for fertilisation.

Figure 2.17: Mosses are bryophytes. These plants do not have internal support and spread across surfaces rather than growing upwards.

Seeds, fruits and flowers can be used to classify plants

Plants can also be grouped into those that produce seeds and those that do not. For example, ferns do not have seeds (they have spores), whereas flowering plants do have seeds.

Plants that produce seeds can be divided into those that produce seeds in cones or in flowers and fruits.

Gymnosperms produce naked seeds that develop in cones. These plants have needle-like or thin leaves, and often grow into tall trees with woody trunks. Because they have large root systems, they can collect water from underground supplies and can grow in many different environments. Pines, firs, cycads and ginkgos are all gymnosperms.

Angiosperms produce seeds in flowers or fruits. There are many different types of flowering plants, and this is the largest group of plants on Earth. Wattles, roses, grass, wheat and eucalypts are all angiosperms.

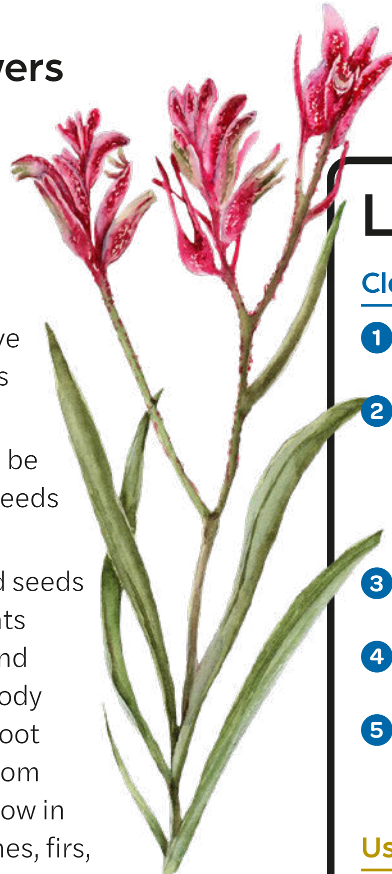


Figure 2.19: This Australian native plant, the kangaroo paw, is an angiosperm because it produces seeds in its flowers.

Table 2.4: Some features used to classify plants

Class	Contains vascular tissue?	Produces seeds?	Method of producing seeds	Examples
Bryophytes	No	No	—	Mosses, liverworts
Ferns	Yes	No	—	Ferns
Gymnosperms	Yes	Yes	Cones	Pine tree
Angiosperms	Yes	Yes	Flowers and fruits	Orange tree

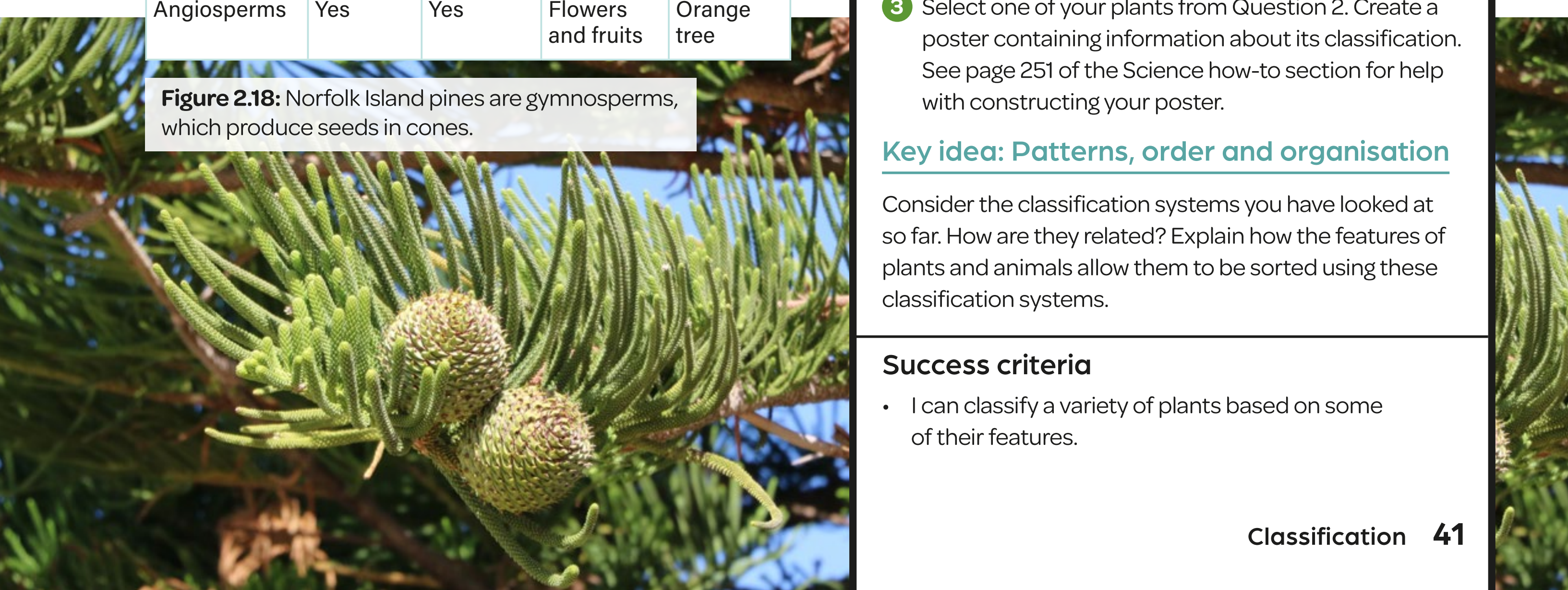


Figure 2.18: Norfolk Island pines are gymnosperms, which produce seeds in cones.

Learning Ladder

Classification

1. Identify an example of a:
   a tracheophyte. b bryophyte.
2. A plant is about 20 cm tall and has a pink flower blooming from a single stem. Into which of the following groups would you classify this plant? Give a reason for your choice.
   A Ferns B Gymnosperms C Angiosperms
3. Is a cherry tree a gymnosperm or an angiosperm? Explain your answer.
4. Compare and contrast the features of bryophytes and tracheophytes.
5. Conduct a search to explore how gymnosperms and angiosperms were classified before their seed-producing methods were understood.

Use and influence of science

1. Identify an issue that plants face as a result of human interference.
2. Describe how our knowledge of plants can help us to grow them.
3. Identify the environmental considerations involved when plants are removed from an area to make space for new housing.

Communicating p. 245

1. Identify some features used to classify plants. Use the correct scientific terminology.
2. **a** In your local area, identify a fern, a gymnosperm and an angiosperm.
   b Construct a table that shows how each plant is classified, based on its features.
3. Select one of your plants from Question 2. Create a poster containing information about its classification. See page 251 of the Science how-to section for help with constructing your poster.

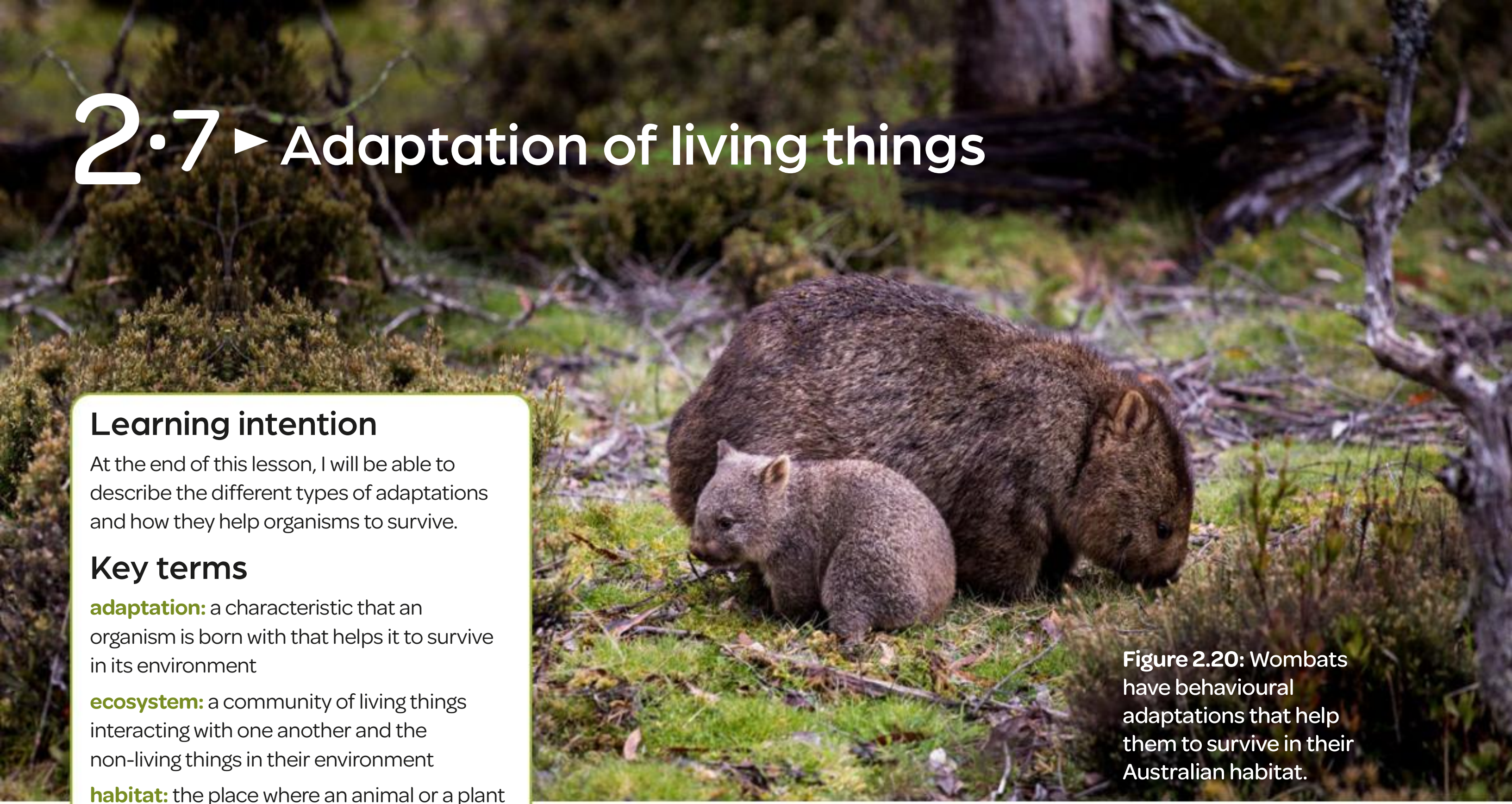
Key idea: Patterns, order and organisation

Consider the classification systems you have looked at so far. How are they related? Explain how the features of plants and animals allow them to be sorted using these classification systems.

Success criteria

- I can classify a variety of plants based on some of their features.

2·7 ► Adaptation of living things



Learning intention

At the end of this lesson, I will be able to describe the different types of adaptations and how they help organisms to survive.

Key terms

adaptation: a characteristic that an organism is born with that helps it to survive in its environment

ecosystem: a community of living things interacting with one another and the non-living things in their environment

habitat: the place where an animal or a plant naturally lives

Investigation 2.7

Investigating structural adaptations, p. 293

Key idea: Patterns, order and organisation

Figure 2.20: Wombats have behavioural adaptations that help them to survive in their Australian habitat.

The characteristics that make organisms able to survive in their environments are called adaptations. Adaptations can be structural, physiological or behavioural.

Behavioural adaptations are something animals do

A behavioural **adaptation** is any behaviour that organisms exhibit that helps them to survive in their **habitat**. For example, a single organism collecting specific objects to build a habitat is a behavioural adaptation. A group of organisms choosing to live together is also a behavioural adaptation that helps them to survive.

In the Australian environment, many organisms display behavioural adaptations. For example, when a wombat is being chased, it runs towards its burrow and then stops suddenly. The predator runs into its back end, damaging its jaw on the wombat's reinforced tailbone.

Figure 2.21: The digestive systems of koalas allow them to eat the waxy, toxic leaves of eucalyptus trees without getting sick.

Physiological adaptations are processes in the body

Physiological adaptations are processes and functions that help organisms to survive. They are triggered in response to the environment.

For example, pregnant female kangaroos can 'pause' the development of their joey if food is scarce. When food is plentiful again, the pregnancy continues. This reaction is controlled by hormones, and is not a conscious choice of the kangaroo, but it does improve the survival rates of joeys.

Structural adaptations are physical features of an organism

A structural adaptation is any physical feature of an organism that helps it to survive in its environment. Physical features include tissue, organs, and any visible features such as tails, bodies and claws.

For example, the thick, brown fur that covers most of a platypus's body is waterproof and insulates against the cold, which allows these animals to hunt for food in cold rivers.

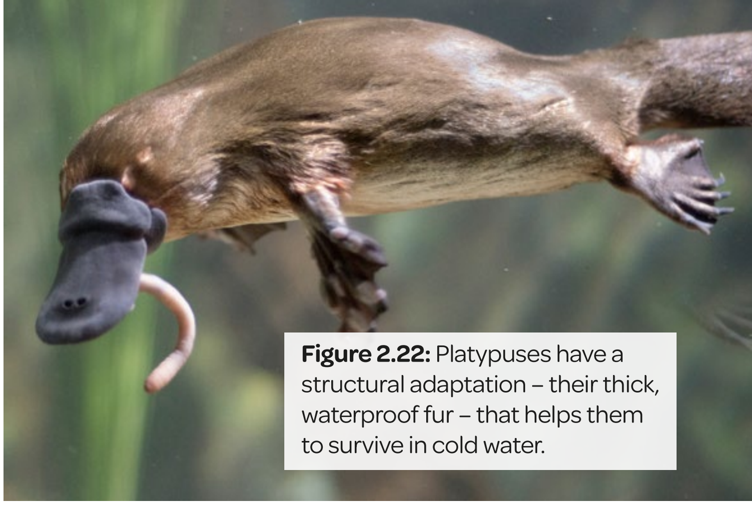


Figure 2.22: Platypuses have a structural adaptation – their thick, waterproof fur – that helps them to survive in cold water.

Australian organisms are adapted to their environments

Adaptations can be seen clearly in many Australian **ecosystems**, such as bushland areas (see Table 2.5).

Table 2.5: Examples of how Australian organisms are adapted to their environments

Organism	Adaptation	Type	Benefit
Eucalyptus tree	Leaves are coated in a waxy substance that helps them to retain moisture	Structural	Helps the tree survive during droughts and in environments with little water
Koala	Digestive systems allow them to eat waxy, poisonous eucalyptus leaves	Physiological	Provides a food source that other living things are not competing for
Musk lorikeet	Nests in eucalyptus trees	Behavioural	Provides a safe place to produce and raise their young

Learning Ladder

Classification

1. For each of the following organisms, identify one structural adaptation that helps it to survive in its Australian habitat.
   a Platypus **b** Wombat **c** Koala **d** Echidna
2. Identify three features of the wombat that would help you to classify it. Explain why you chose each feature.
3. Explain how two of the structural adaptations you identified in Question 1 help the organism to survive.
4. Look at Figures 2.21 and 2.22. Discuss how the differences in the feet of the koala and the platypus help them to adapt to their environments.

Nature and development of science

1. Identify two problems that the adaptations of organisms help to solve.
2. Describe how scientists from different branches may collaborate to observe adaptations of the platypus.
3. Explain how making a range of observations about an animal you have identified could help scientists better understand it.
4. Propose and explain how animal adaptations may have influenced the use of classification tools.
5. Analyse how adaptations can be interpreted differently by people with different scientific worldviews.

Questioning and predicting

p. 222

1. From the following questions, identify the most appropriate one for investigating the structural adaptations of tropical birds.
   A How do the structural adaptations of tropical birds help them to survive in a rainforest habitat?
   B What features are common to all tropical birds?
   C How does rainfall affect tropical birds' flight patterns?
2. If a specific animal catches and feeds on insects, predict three structural adaptations you expect it to have.
3. Construct a scientific question for investigating the impact of one of the adaptations you identified in Question 2. Relate this adaptation to a specific organism that you know has this feature.

Key idea: Patterns, order and organisation

Humans also have behavioural, physiological and structural adaptations. Propose two characteristics of humans that fall into each category. Justify each classification.

Success criteria

- I can describe the three different types of adaptations.
- I can describe how these adaptations help organisms to survive.

2·8 ▸ First Nations Peoples' systems of classification

Learning intention

At the end of this lesson, I will be able to explain some of the ways Aboriginal and Torres Strait Islander Peoples classify plants and animals.

Key terms

Ancestors: the people we are descended from

spirits: the supernatural beings that many First Nations Peoples believe exist; can be associated with particular places, objects and rituals; are often connected with Dreaming stories

Key idea: Patterns, order and organisation

First Nations classification systems are based on a deep understanding and vast knowledge of living things.

First Nations classification systems are complex webs

The systems used by Aboriginal and Torres Strait Islander Peoples to group objects and organisms consider many factors (see Table 2.6).

Figure 2.23: Canoe trees like this one all have large trunks and thick bark.

Table 2.6: Some of the factors Aboriginal and Torres Strait Islander Peoples use to classify objects and living things

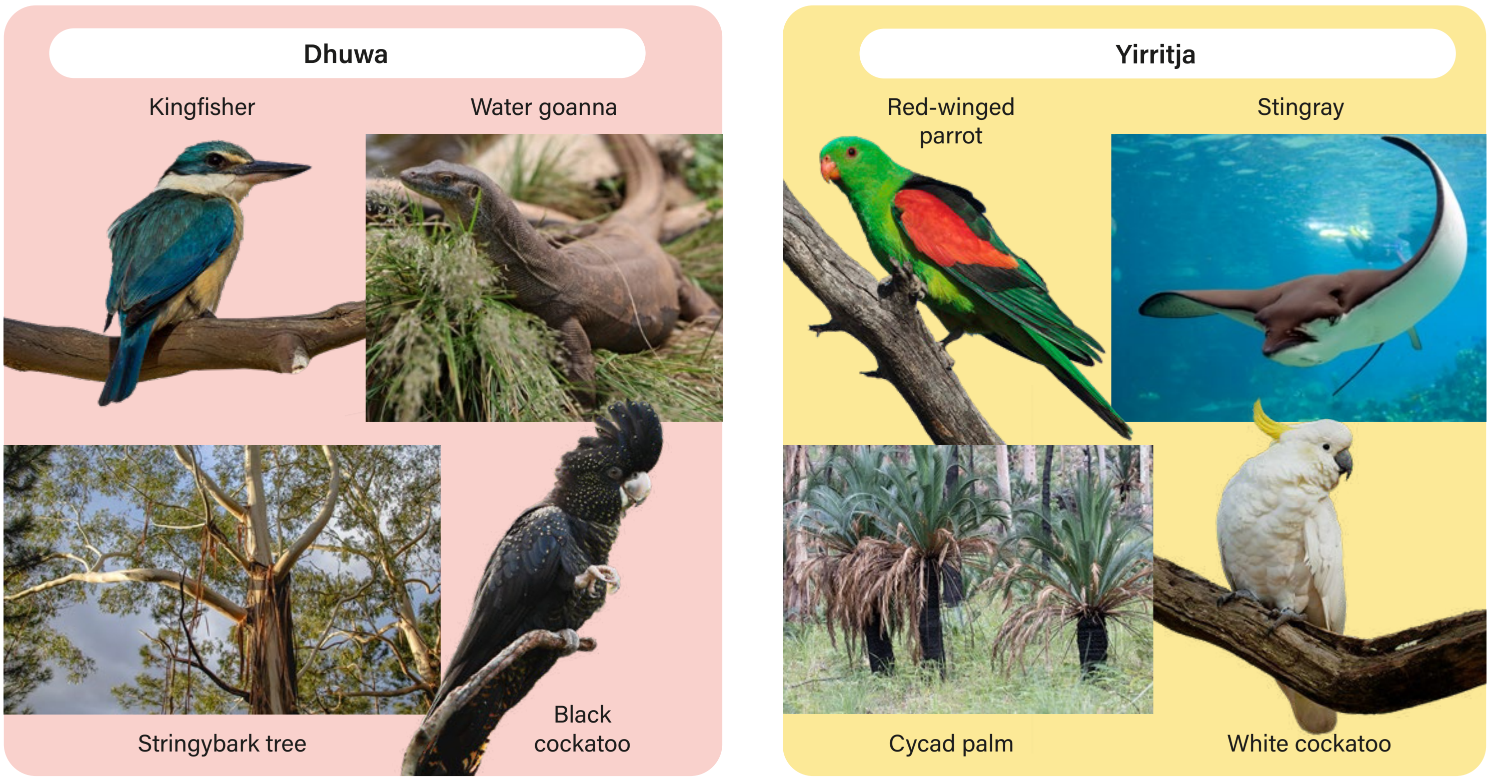
Living or non-living	Edible or non-edible
The organism's age	The organism's size
Venomous or non-venomous	The organism's sex
Status of the organism (e.g. within its herd)	The object or organism's observable features
Where the organism lives (e.g. coastal or inland)	Which stage of its breeding cycle the organism is in
The value of the object or the organism to a First Nations community	Use of the organism when alive and when dead (e.g. as food, medicine, tools, clothing)

Plants and animals are sorted by their use

One way First Nations Peoples group living things is by how they are are used. For example, some trees (including swamp she-oaks, stringybarks and mulga trees) are classified as 'canoe trees' because First Nations Peoples made canoes by removing the bark from these trees.

The Dhuwa and Yirritja classification system divides the universe into two halves

The Dhuwa and Yirritja classification system is fundamental to the culture of the Yolŋu People, who live in north-east Arnhem Land. In this system, *everything* in the universe is classified as either Dhuwa or Yirritja: the seasons, individuals, animals, plants, areas of land, waterways, clouds, **spirits**, **Ancestors** and winds.



▲ **Figure 2.24:** The Yolŋu People classify everything as either Dhuwa or Yirritja.

Learning Ladder

Classification

1. Examine Table 2.6. List the observable features of living things that have been used as criteria for classification.
2. Examine Figure 2.24. Classify the organisms pictured in this figure based on the criteria in Table 2.6.
3. Identify the two categories Yolngu People use to classify objects and organisms.

Nature and development of science

1. Identify a problem that the classification of canoe trees can help to solve.
2. Refer again to Table 2.6. Suggest how First Nations Peoples use classification in multiple different ways.

Communicating p. 245

1. Refer again to Figure 2.24. Use scientific terminology to describe two organisms that are:
   a Dhuwa. b Yirritja.
2. Describe the differences between the Linnaean and First Nations classification systems.
3. Create a digital presentation of the organisms you identified in Question 1.
4. Discuss how using digital simulations to display ideas to your audience could improve your presentation from Question 3.
5. Adapt your presentation from Question 3 into a puppet show for kindergarten students.

Key idea: Patterns, order and organisation

Refer again to Table 2.6. Outline how the characteristics used to classify living things in the First Nations and Western science classification systems are different or the same.

Success criteria

- I can explain some of the ways Aboriginal and Torres Strait Islander Peoples classify plants and animals.

2.9 ▸ Key idea: Patterns, order and organisation – classification of the quokka

Figure 2.25: The scientific name of the quokka is *Setonix brachyurus*.

Learning intention

At the end of this lesson, I will be able to understand why it is important to use classification to understand the world around me.

Key term

nocturnal: active during the night

Key idea: Patterns, order and organisation

It is important to be able to use classification systems to organise the world around us. We can apply these systems to all living things. For example, the quokka – a **nocturnal** Australian animal – can be organised into the categories of the Linnaean classification system.

Why is a quokka classified as a living thing?

We saw in Section 1.1 that organisms must have seven biological characteristics to be considered 'living' by scientists. The quokka has all seven of these features (see Table 2.7).

Table 2.7: Characteristics of quokkas that classify them as living things

Biological characteristic	Description	Quokka behaviours and features
Growth	The organism gets bigger and develops over time.	A baby quokka is the size of a bean and weighs around 35 grams; adult quokkas weigh between 2.5 and 5 kilograms and their bodies are around 40–54 centimetres long.
Movement	The organism can move part or all of itself.	Quokkas run and hop along the ground using their large hind legs and long tails.
Nutrition	The organism takes in nutrients.	Quokkas take in nutrients by eating plants, such as native grasses, leaves and berries.
Reproduction	The organism can produce offspring.	Quokkas give birth to live young.
Response to stimuli	The organism can respond to changes in the environment.	Quokkas shelter in dense vegetation during the day when it is hot, and are active at night when it is cooler.
Respiration	The organism can convert nutrients into energy.	Quokkas are made of cells; cells use respiration to transform into energy the nutrients in the plants that quokkas eat.
Waste removal	The organism can get rid of waste products.	Quokkas get rid of both urine and faeces.

How do we classify the quokka?

The species of the quokka can be classified using the Linnaean system of classification (see Table 2.8).

Table 2.8: Classification of the quokka in the Linnaean system

Classification level	Quokka classification	Description
Domain	Eukaryota	Organisms with specialised cells
Kingdom	Animalia	Animals
Phylum	Chordata	Animals with a cord along their back
Class	Mammalia	Mammals: have hair and live young
Order	Diprotodontia	Marsupials: have a pouch
Family	Macropodidae	Macropods: have large hind legs and long tails
Genus	*Setonix*	Specific to the quokka only
Species	*brachyurus*	

Therefore, the full scientific name of the quokka is *Setonix brachyurus*.

Why is classification important?

Classification systems enable scientists to communicate to others their understanding of the world and help us to see the patterns in the living things around us. The criteria for classifying living things and the Linnaean system of classification can be applied to anything you see or know of.

Figure 2.26: The quokka is a herbivore, which means it eats plants to obtain nutrients such as glucose.

Learning Ladder

Classification

1. Identify two physical features of macropods.
2. Identify the seven biological characteristics of all living things used in classification.
3. Quokkas are closely related to kangaroos and wallabies. Explain why this is the case, using terms from the Linnaean system of classification.
4. Consider the photos of the quokka. Identify a similar organism, and compare and contrast its features with those of the quokka.
5. The quokka was first described by Western scientists as 'a kind of rat as big as a common cat'. Does this match the current classification of the quokka? Analyse what has changed since this statement was made.

Use and influence of science

1. Identify an issue we would face if we could not categorise organisms in the world around us.
2. Describe how knowledge of classification can be useful in countries like Australia, which has many dangerous and venomous creatures.
3. Explain an environmental consideration that classifying species assists with. (*Hint:* How can we protect species?)
4. There are several policies relating to the quokkas of Rottnest Island. Use secondary research to identify and discuss the impact of two of these policies.
5. Elaborate on your response to Question 4 by considering different perspectives or worldviews that might have contributed to the development of each policy.

Communicating *p. 245*

1. Identify three scientific terms used when listing the seven biological characteristics of living things.
2. Describe a way you could communicate information about the diet of the quokka.
3. Create a poster that provides information about the quokka. Highlight the features that justify its classification as a living thing.
4. Construct a digital flowchart that shows the classification of the quokka.
5. Select a plant or animal from your local area. Use the Linnaean system of classification to classify it, from domain to species.

Success criteria

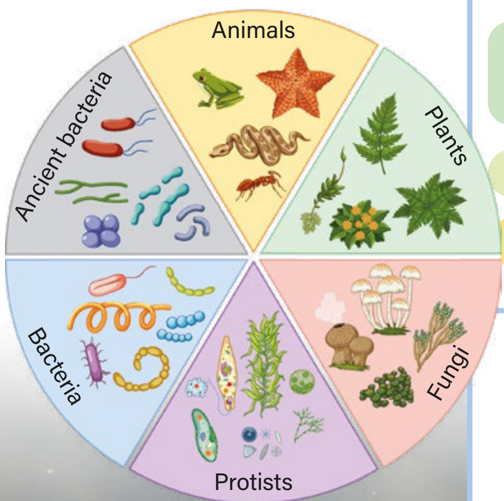
- I can describe why classification systems are important.
- I can use classification systems to identify patterns and to organise the world around me.

Summary

All living things are made of cells and share biological characteristics: they can grow, move, reproduce, respond to stimuli, take in nutrients, convert nutrients to energy and excrete waste.

Classification level	Classification for brush-tailed rock wallaby
Domain	Eukaryota (organisms with specialised cells)
Kingdom	Animalia (animals)
Phylum	Chordata (animals with a cord along their back)
Class	Mammalia (mammals) (animals with hair and live young)
Order	Marsupialia (marsupials) (animals with a pouch)
Family	Macropodidae (macropods) (animals with large hind legs and long tails, e.g. wallabies, kangaroos, pademelons)
Genus	*Petrogale* (rock wallabies)
Species	*Petrogale penicillata* (brush-tailed rock wallaby)

Very general → Very specific

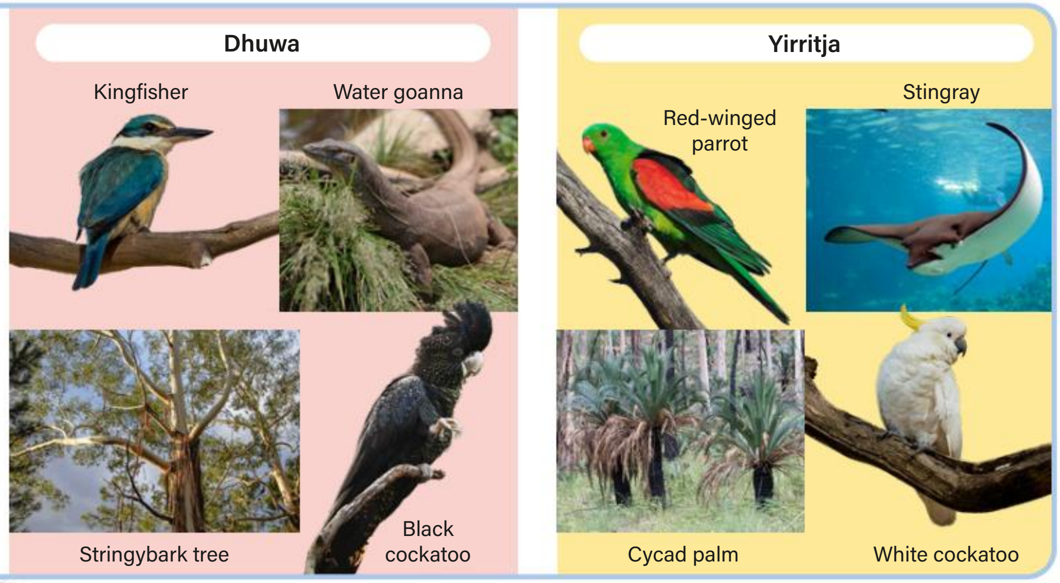


In biology, taxonomists use the Linnaean system of classification to sort living things from domain (broad) to species (specific). An animal's full scientific name is its genus and species names together.

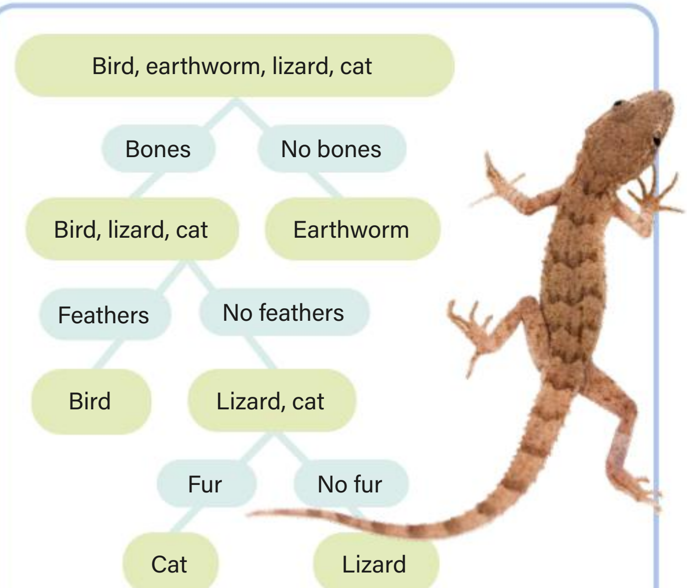
Classification keys – including dichotomous and branching keys – can be used to sort organisms by their specific features.

Animals have many adaptations, including structural features, that can help in classifying them into groups. These features also help them to survive, like the water-resistant fur of the platypus.

First Nations Peoples use complex classification systems, which can include many factors such as the age and location of living things and their value to specific communities.



Animals can be classified as vertebrates (have a backbone) or invertebrates (no backbone). Most invertebrates have a hard protective exoskeleton (for example, insects).



Objects and organisms can be categorised using dichotomous keys and branching keys, which help to group things based on their similarities.

Plants can be classified as tracheophytes (vascular) or bryophytes (non-vascular). Tracheophytes can be further divided into those that produce seeds and those that do not.

All angiosperms (flowering plants) produce seeds.

Key idea: Patterns, order and organisation

Our understanding and use of classification can be applied to all living things, in order to organise the patterns we observe and to better understand the world around us.

Masterclass

Steps in progression		1	2
Science understanding	Classification	Identify three features of the delicate mouse in Figure 2.27.	Describe how these features may help to classify this mouse.
Science as a human endeavour	Nature and development of science	Identify one problem with studying animals such as the delicate mouse. Propose a solution to this problem.	Identify three different types of scientists who might be involved in studying the delicate mouse. Why is each one important?
Science as a human endeavour	Use and influence of science	Climate change is a socio-scientific issue. Identify one way it may impact the delicate mouse.	Describe how our knowledge of climate change may affect the habitat of the delicate mouse.
Science inquiry	Questioning and predicting	'How does the amount of yearly rainfall affect the population size of the delicate mouse?' Is this a scientific question? Why or why not?	Use the images of the delicate mouse to predict the colours of its habitat. Consider that it would need to be able to hide from desert predators.
Science inquiry	Planning and conducting	Identify a piece of equipment that scientists have used to help them classify the new species of delicate mouse.	Describe three safety practices required when conducting field work in the desert to observe the delicate mouse.
Science inquiry	Communicating	Identify two scientific terms used to describe the delicate mouse.	Describe a way you could communicate information about the habitats and distribution of the delicate mouse species to other scientists.

Figure 2.27: In 2024, scientists confirmed they had found two new species of the delicate mouse in Australia.

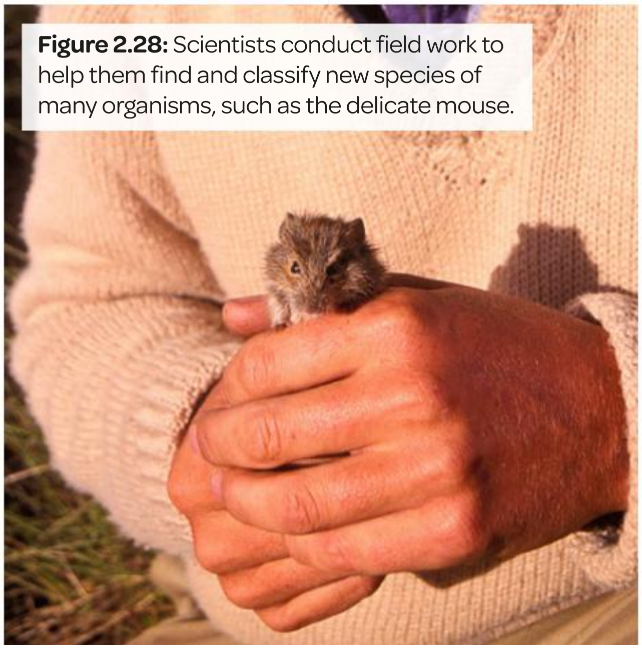


Figure 2.28: Scientists conduct field work to help them find and classify new species of many organisms, such as the delicate mouse.

Demonstrate your understanding

3	4	5	
Explain how classification conventions can be used to distinctly organise the three species of delicate mouse.	Compare and contrast the features of the delicate mouse to those of another organism that lives in the Australian desert.	Analyse how using technologies has allowed scientists to change the classification of these species of mice.	
Explain how evidence gathered by scientists allowed them to change the classification of the delicate mouse.	Discuss how our understanding of classification may have developed over time, as scientists gained access to new technologies.	Analyse how the different understandings of the scientists you identified in step 2 allowed us to develop new knowledge.	
Explain the ethical and environmental considerations associated with using new technologies to address the issue of climate change.	Discuss the impact a worldwide response to climate change would have, using the habitat of the delicate mouse as an example.	Analyse how our communication of climate change has impacted society's view of it. How will this affect species that live in the desert?	
Construct a question that could be used for the investigation described in step 5 of the 'Planning and conducting' questions.	Use your question from step 3 to develop a hypothesis, including the independent and dependent variables.	Evaluate your question and prediction from steps 3 and 4 for their scientific validity. Refer to the Science how-to section on page 225 if you need help.	How-to p. 222
Identify the independent and dependent variables of the scientists' study. Propose three variables that should be controlled.	Propose a way that scientists could ensure they collect precise data about the delicate mouse, such as its size and habitat.	Design a first-hand investigation to record the average mass of each delicate mouse species, considering animal ethics.	How-to p. 226
Use secondary sources to construct a poster to communicate this information from step 2.	Explain how you could digitally present data on the genetics of the different species of delicate mouse.	Edit your poster from step 3 into a written presentation that could be used to teach Year 5 students about the delicate mouse.	How-to p. 245

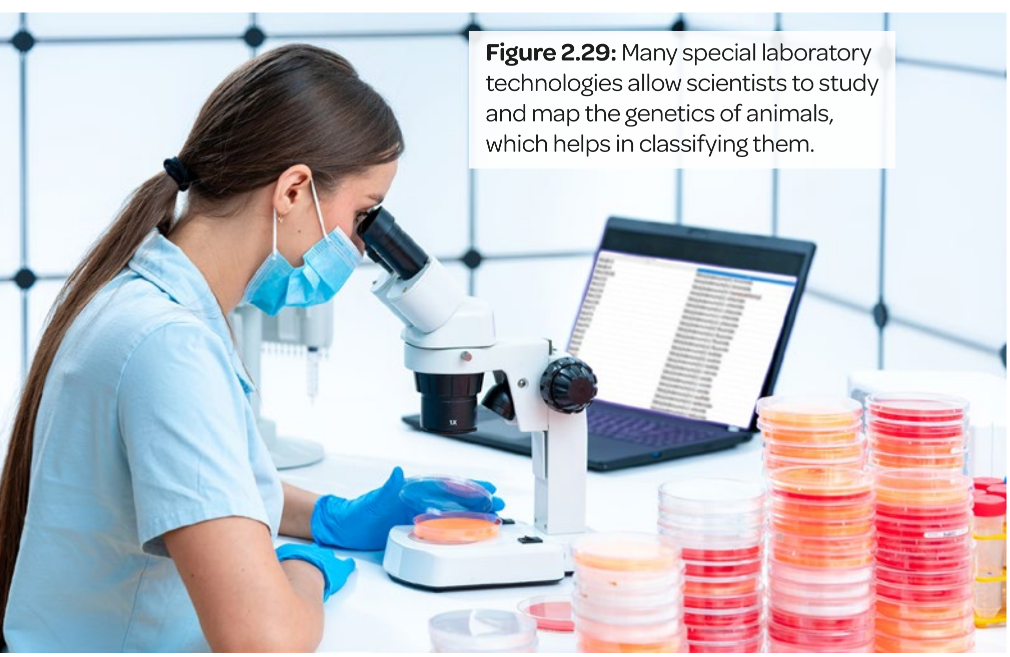


Figure 2.29: Many special laboratory technologies allow scientists to study and map the genetics of animals, which helps in classifying them.

New Australian mice scamper around Australian deserts

In February 2024, Australian scientists confirmed they had found two new species of native mice in the Australian desert. These mice are types of the 'delicate mouse'. While it has previously been thought there was only one species of this Australian marsupial, scientists have now confirmed that there are at least three distinct species that inhabit different parts of the Australian desert. The scientific names of these species are: *Pseudomys delicatulus*, *Pseudomys pilbarensis* and *Pseudomys mimulus*.

3.0 Ecosystems

An ecosystem is a biological community of living things such as plants and animals, and of non-living things such as air and water. Food chains and webs can show how living things interact, based on a variety of forms and functions.

Many people struggle to share their home with spiders, but killing them can have a big impact on an ecosystem. Spiders eat insects and pests that might otherwise damage natural plant environments and ruin crops. They are also a food source for animals such as birds, so removing them from an ecosystem can be devastating.

Learning Ladder

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

Steps in progression	Science understanding	Science as a human endeavour	
	Biological science: Ecosystems	Nature and development of science	Use and influence of science
5	I can analyse how ecosystems respond to internal and external changes	I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations
4	I can interpret and predict the effects of environmental changes on ecosystems	I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues
3	I can represent flows of matter and energy in ecosystems	I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances
2	I can describe relationships between a variety of organisms	I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society
1	I can identify features of an ecosystem	I can recognise scientific problems and solutions	I can identify socio-scientific issues

Figure 3.1: Organisms must interact in order to survive in shared habitats and ecosystems.

Science inquiry

Steps in progression	Processing, modelling and analysing	Evaluating	Communicating
5	I can analyse processed data for patterns, trends, relationships and anomalies	I can evaluate conclusions and claims with reference to conflicting evidence and unanswered questions	I can communicate scientific findings and arguments for specific purposes to specific audiences
4	I can identify and discuss trends and/or patterns in a range of dataset representations	I can create evidence-based arguments to justify conclusions or evaluate claims	I can use digital technologies to organise and communicate data and information
3	I can process data by using mathematical relationships and/or constructing graphs	I can use science-based explanations to support investigation findings	I can prepare a variety of representations to communicate ideas and findings
2	I can organise and display data using tables, keys and/or models	I can describe different types of errors in an investigation method	I can select appropriate formats to communicate ideas and findings
1	I can identify data from tables and graphs	I can identify errors and assumptions in an investigation	I can identify scientific terminology used to communicate information

3·1 ▸ Ecosystem basics

Learning intention

At the end of this lesson, I will be able to distinguish between ecosystems, communities and habitats, and between biotic and abiotic factors.

Key terms

abiotic: non-living

biotic: living

community: a naturally occurring group of animals, plants and other organisms

consumer: an organism that gains energy by consuming other living organisms

decomposer: an organism that breaks down and recycles decaying matter

ecosystem: a community of living things interacting with one another and the non-living things in their environment

habitat: the place where an animal or a plant naturally lives

producer: an organism that makes its own food using energy from the Sun

Investigation 3.1

Identifying community members in a terrestrial ecosystem, p. 294

Key idea: Form and function

An **ecosystem** is an area that contains living and non-living things and their environment. Ecosystems can be very small, such as a pond, or very large, such as an island.

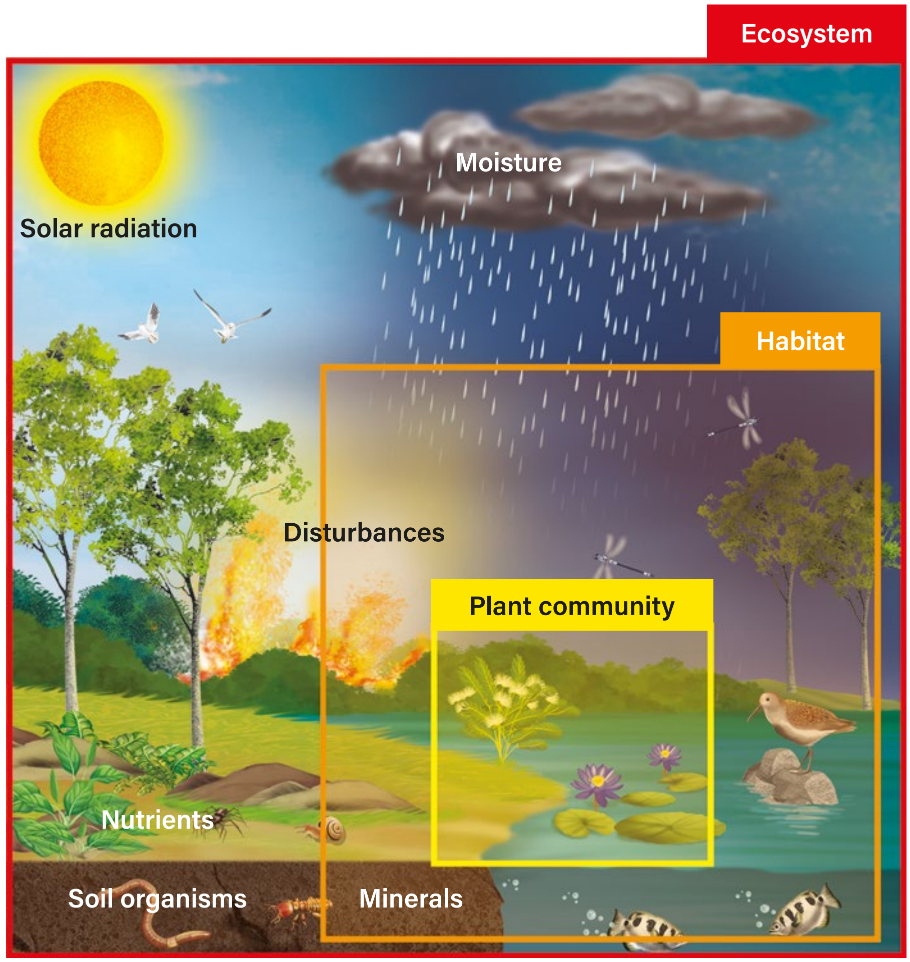


Figure 3.2: An ecosystem is an area that contains living and non-living things and their environment.

Communities are made up of different species

A **community** is made up of populations of all the different species that live in the ecosystem. All organisms within a community depend on each other for energy, nutrients and survival. **Producers** convert the energy from the Sun into chemical energy that can then be used by other organisms. **Consumers** obtain their energy by eating other organisms.

Decomposers, such as bacteria and fungi, recycle the nutrients from dead organisms and make them available to other species in the ecosystem.

The living things in an ecosystem are referred to as **biotic** factors. The non-living things, such as soil and water, are known as **abiotic** factors.

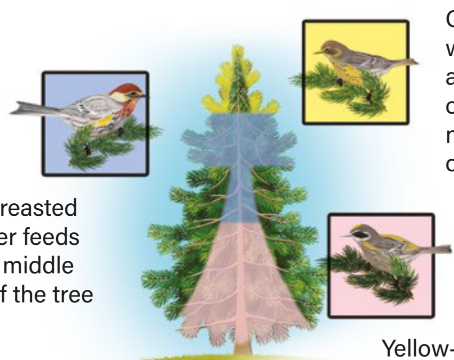
A habitat contains living and non-living factors

A **habitat** is the natural environment where a species or an organism lives. A habitat must supply food and water, shelter and protection, and mates to reproduce with. Every species needs specific conditions in a habitat; a koala and a polar bear would not live in the same place because they have different requirements.

Habitats can change over time. This might be due to naturally occurring events, such as a volcanic eruption, or to human causes, such as climate change or land clearing. The introduction of a new, non-native species can also affect native habitats and the organisms living there. These factors will be explored in more depth later in the chapter.

Each organism has an ecological niche

Each organism has a particular role within the ecosystem; this is its ecological niche. An organism's niche includes the interactions it has with other organisms, the type of food it eats, where it lives and how it reproduces. Only one organism can fill a specific niche in an ecosystem. Many different species can co-exist within an ecosystem if no two species have the same niche.



▲ **Figure 3.3:** Feeding zones of warblers. Each warbler species occupies a different niche. The birds feed in different parts of the spruce tree, so they are not competing with each other for food.

Introduced species cause problems if they take over a niche and out-compete the native animals. If an organism disappears from an ecosystem, there will be flow-on effects throughout the entire community. For example, if a pollinator disappears, plants cannot reproduce. This limits the amount of food available to the herbivores and, in turn, to the carnivores.

Learning Ladder

Ecosystems

1. Outline the general components of an ecosystem.
2. Copy and complete.
   A community is made up of __________ of all the different ___________ that live in the ecosystem. All organisms within a community _____________ on each other for ___________, __________ and __________. Each organism maintains its ecological niche within its specific __________.

Nature and development of science

1. Propose a problem that would arise if only biotic factors were found in ecosystems.
2. Biology is the study of living things, and geology is the study of rocks. Copy and complete.
   Biologists focus on the ___________ factors in an ecosystem, while geologists focus on ___________ factors.
3. Explain how evidence about what organisms eat helps in classifying them as producers, consumers or decomposers.

Communicating p. 245

1. Classify the following as either biotic or abiotic: trees, wind, birds, sunlight, rain, insects, rocks, soil, flowers.
2. Construct a visual way (such as a chart) to communicate the abiotic and biotic factors listed in Question 1.
3. Construct a digital diagram of a habitat. Label and describe all its parts, including biotic and abiotic factors.
4. Expand your digital diagram from Question 3 into an informative slide presentation.
5. Adapt your presentation from Question 4 into a comic strip suitable for Grade 3 students to read independently.

Key idea: Form and function

Choose a wild animal and describe its habitat. Outline the structural features that form its body. Propose how these features might be related to its habitat, function and survival.

Success criteria

- I can distinguish between ecosystems, communities and habitats.
- I can classify factors as biotic or abiotic.
- I can describe the difference between a habitat and a niche.

3·2 ▸ Interactions between organisms

Figure 3.4: Predators kill and feed on their prey.

Learning intention

At the end of this lesson, I will be able to describe the different ways organisms interact in an ecosystem and keep it in balance.

Key terms

adaptation: a characteristic that an organism is born with that helps it to survive in its environment

parasite: an organism that lives in or on another organism, causing it harm

pollinator: an organism that transfers pollen from the male part of a plant to the female part

predator: an organism that kills and feeds on prey

prey: an organism that is killed by a predator

Key idea: Form and function

There is more to interactions in an ecosystem than just who eats whom. Interactions between organisms can be helpful, such as the interaction between bees and flowers, or harmful, such as the interaction between a parasite and its host. Table 3.1 describes some ecological relationships.

Table 3.1: Ecological relationships

Interaction	Effects on the population	Example
Mutualism	The interaction is beneficial to both species.	A cassowary eating the fruit of plants and distributing the seeds in its dung
Commensalism	One species benefits and the other species is unaffected.	A staghorn fern growing on the branch of a tree
Competition	Both species are negatively affected because they compete for resources.	Sugar gliders competing with superb parrots for nesting hollows
Predator–prey	The predator benefits and the prey is harmed or killed.	A bronze whaler shark eating sardines
Parasitism	The parasite benefits and the host is harmed.	Mistletoe taking nutrients from a host tree

Competitors compete for resources

Competition often happens when organisms need the same limited resource (such as food) in the same ecosystem. Competitors can be different species or members of the same species. Depending on the amount of food available, organisms may be harmed, may starve or may have to find a new food source.

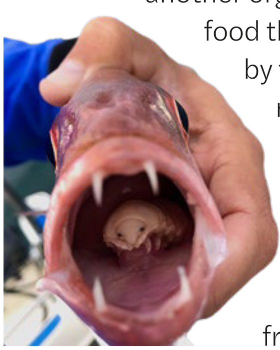
Some members of the same species will even compete for a mate; it is all part of trying to survive and thrive.

Plants also compete for resources, but not in the same way as animals. Plants compete for space, light, water and nutrients, which are the things they need to produce energy. Some plants will grow and survive, while others will die.

Predators and prey keep each other in balance

Predators are organisms that kill and feed on other organisms: their **prey**. For example, a fox is a predator and its prey is a rabbit. Predator–prey relationships might seem ruthless, but their interactions play a crucial role in an ecosystem: they stabilise the numbers of prey organisms. If the numbers of prey increase, then numbers of predators will increase, which keeps the predator–prey ratio balanced. Predators have some special **adaptations** that enable them to catch their prey, such as good vision or hearing, sharp claws or teeth, and strong jaws.

Parasites are a type of predator that live on (or in) another organism where they feed on food that has already been digested by the host. Parasites are usually much smaller than their prey and harm the other organism without killing it. For example, the hookworm lives in the intestines of its human host where it feeds on nutrients from digested food.



▲ **Figure 3.5:** Parasites live on (or inside) their host organism. The parasitic isopod *Cymothoa exigua* attaches to a fish's tongue, eventually replacing it with its own body!

Pollinators and plants help each other

Flowering plants have female and male sex organs. For fertilisation to occur, they need a **pollinator**. A pollinator transfers pollen from the male sex organ of plants to the female sex organ.

Bees are important pollinators: without bees, a lot of plant life would cease to exist. The interaction is beneficial for the plant, which is able to reproduce, and for the bee, which gets to take a meal of nectar back to its colony. Birds, some lizards and even monkeys can also be pollinators.

Figure 3.6: Bees as pollinators enable plants to reproduce.

Learning Ladder

Ecosystems

1. Brainstorm and list as many different predator–prey relationships as you can think of.
2. Competition occurs in every ecosystem.
   a Define 'competition' in your own words.
   b Outline some resources that plants and animals compete for.
3. Explain, using an example, how predators and prey keep each other in balance.

Nature and development of science

1. Predator–prey relationships are difficult for scientists to observe. Propose a solution to this problem.
2. Describe a predator–prey scenario that would require different types of scientists to collaborate in conducting an appropriate analysis.
3. A parasite is observed feeding on spinach leaves. Propose how this observation might change our understanding of a parasite.
4. The meanings of the interactions listed in Table 3.1 have developed over time. Conduct a search to see if you can find outdated or contradictory theories about ecological relationships.
5. Analyse and discuss the different scientific perspectives that emerged in your research for Question 4.

Processing, modelling and analysing p. 230

1. Use Table 3.1 to classify the following interactions.
   a Bandicoots feed on insects in your backyard.
   b Dung beetles feed on kangaroo dung. The kangaroos are unaffected.
   c A tick sucks blood from a wallaby.
   d A cleaner shrimp removes parasites from a sea turtle.
2. Construct a table to organise the brainstorm you conducted for Question 1 under 'Ecosystems' above.

Key idea: Form and function

There has been a worldwide decline in the number of bees. Consider their form and function and propose why you think this is occurring. Suggest what could be done to protect and increase bee populations.

Success criteria

- I can describe the different ways organisms interact in an ecosystem.
- I can describe how interactions, including the role of pollination, keep ecosystems in balance.

3·3 ▸ Abiotic factors in ecosystems

Learning intention

At the end of this lesson, I will be able to discuss abiotic components of the environment and their impact on ecosystems.

Key term

zone of tolerance: the range of an abiotic factor that an organism can survive in

Investigation 3.3

Measuring abiotic factors, p. 295

Key idea: Form and function

Factors such as water availability, soil type, temperature and the availability of nutrients affect what organisms will live in an ecosystem. Changes in the normal level of abiotic factors also affect the rest of the ecosystem.

Abiotic factors affect what can live in an ecosystem

Abiotic factors are chemical and physical factors within an ecosystem. They include:

- rainfall and water availability
- soil type
- temperature
- pH of soil or water
- sunlight
- nutrient availability in soil or water
- gas (oxygen and carbon dioxide) availability
- salinity (saltiness) of soil or water.

The abiotic factors in an ecosystem affect what can live there. For example, the amount of sunlight, nutrients and water determines the types of plants that live in an ecosystem. This, in turn, affects which consumers can live there.

Figure 3.7: Structural, behavioural and physiological adaptations

Organisms have adaptations to abiotic factors

Organisms have evolved adaptations to help them survive in their environment (see Figure 3.7). The adaptations can be:

- **structural:** a feature of an organism's body; for example, the sharp claws of a koala help it to climb trees to reach its food source
- **behavioural:** the way an organism responds to its environment; for example, the huddling of emperor penguins to stay warm
- **physiological:** a process inside an organism's body; for example, a camel's ability to retain water by producing low volumes of urine.

Organisms can still only tolerate specific levels of each abiotic factor. If the level of an abiotic factor moves out of this **zone of tolerance**, the organism will not survive.

Coral bleaching is caused by abiotic factors

Coral bleaching is an example of what happens when abiotic factors move out of the zone of tolerance.

Corals live in a mutual relationship with algae called zooxanthellae. The algae live inside the structure of the coral. The coral provides the algae with a home, and the algae photosynthesise and provide the coral with 90 per cent of its energy requirements. The algae are also responsible for the coral's colour.

If water temperature or pollution levels exceed the coral's zone of tolerance, the coral expels the algae and becomes bleached. If temperatures and pollution levels return to normal, the coral allows the algae to return, and it recovers. If the levels remain too high for too long, then the coral dies.

The optimum water temperature range for most reef-building corals is 20–32 °C, although different species have their own zones of tolerance. Increasing temperatures in Australian waters have led to coral bleaching all along the Great Barrier Reef.

Figure 3.8: A marine biologist measures bleached coral.

Learning Ladder

Ecosystems

1. List five abiotic factors you observed in an ecosystem you visited recently.
2. Describe three abiotic factors that are important for a:
   - **a** bird.
   - **b** saltwater fish.
3. Construct a Venn diagram to display the differences between biotic and abiotic factors. Include examples.
4. Discuss, using a specific example, what is meant by an organism's tolerance level to an abiotic factor.
5. Predict ways that a kangaroo might adapt if:
   - **a** pollution causes the salinity level of a freshwater pond to increase.
   - **b** the summer months become drier and hotter.
   - **c** grazing paddocks are cleared for development.

Use and influence of science

Identify a specific environmental, economic or social issue that could threaten ecosystems.

1. Outline the issue and describe the threat it creates.
2. Describe how scientific knowledge could address the issue outlined in Question 1.
3. Explain how the issue outlined in Question 1 impacts scientific advances.

Evaluating

p. 239

Consider Investigation 3.3, 'Measuring abiotic factors' (page 295). Read the aim, materials and method.

1. Identify one assumption this investigation makes.
2. Identify and describe two different types of errors that could affect the results. Classify each as either an error in the method or a mistake that can be avoided.

Key idea: Form and function

Conduct research to compare the abiotic factors in the Daintree Rainforest (Queensland) and the Simpson Desert (Central Australia). Find out about rainfall (water availability), temperature range and nutrient availability in the soil in these locations. How do these factors influence how organisms function in these ecosystems?

Success criteria

- I can identify at least three examples of abiotic factors.
- I can explain how abiotic factors can determine what organisms live in an ecosystem.

3·4 ▸ Matter flows through ecosystems

Learning intention

At the end of this lesson, I will be able to explain the process and importance of how matter flows through ecosystems.

Key terms

atmospheric nitrogen: nitrogen in the atmosphere

mutualism: a relationship between two organisms in which both organisms benefit

Key idea: Form and function

Figure 3.9: Soybean roots contain nodules of bacteria that take in nitrogen from the soil.

Figure 3.10: Mushrooms are a type of fungi that help other plants share nutrients by cycling matter through ecosystems.

Matter cannot be created or destroyed. Matter cycles through different parts of ecosystems, including the atmosphere, soil and organisms. The atoms that make up your body were once part of the air you breathed and the food you ate. The atoms in a steak came from the plants that the cow ate, and before that from the carbon dioxide, water and nutrients in the plants.

Nitrogen is an important element for life

Nitrogen (N) is an important element that cycles through ecosystems. Nitrogen is in amino acids, the building blocks of proteins, which are essential for all life. Nitrogen is the most abundant element in the atmosphere, making up approximately 78 per cent of air, where it mostly exists as molecular nitrogen (N_2).

Plants take up inorganic nitrogen (from non-living sources) through their roots from the soil. In this way, nitrogen enters the biosphere and cycles through living things.

Nitrogen cycles from the atmosphere

Plants cannot use **atmospheric nitrogen**. They need to obtain nitrogen from the soil (through their roots) in the form of nitrate (NO_3^-). They use this nitrogen to make amino acids.

Most nitrogen is transformed by different species of nitrogen-fixing bacteria into forms that plants can use. This usually happens in several steps, each involving a different species of bacteria. Some of these bacteria live in the roots of legumes (for example, peas and beans). This **mutualism** relationship benefits both the bacteria and the plant.

Herbivores (animals that only eat plants) produce proteins from the amino acids in the plants they eat. When a herbivore is consumed by a higher-order predator, the amino acids are then used by the predator. Decomposers such as bacteria and fungi break down the amino acids in dead matter, releasing nitrogen back into the soil for reuse by plants.

Other elements also cycle through ecosystems

Carbon, oxygen, hydrogen and phosphorus also cycle through ecosystems. All these elements are important for the formation of molecules that are vital for life. Carbon, oxygen and hydrogen cycle through ecosystems by means of the processes of photosynthesis and cellular respiration. They move from inorganic molecules, such as carbon dioxide, molecular oxygen (O_2) and water, into organic molecules, such as glucose and other carbohydrates, which are then passed up through the food chain.

Phosphorus plays an important role in the formation of DNA. Plants take up phosphorus from soils and convert it into molecules that are then passed up through the food chain, returning to the inorganic forms through excretion and decomposition.

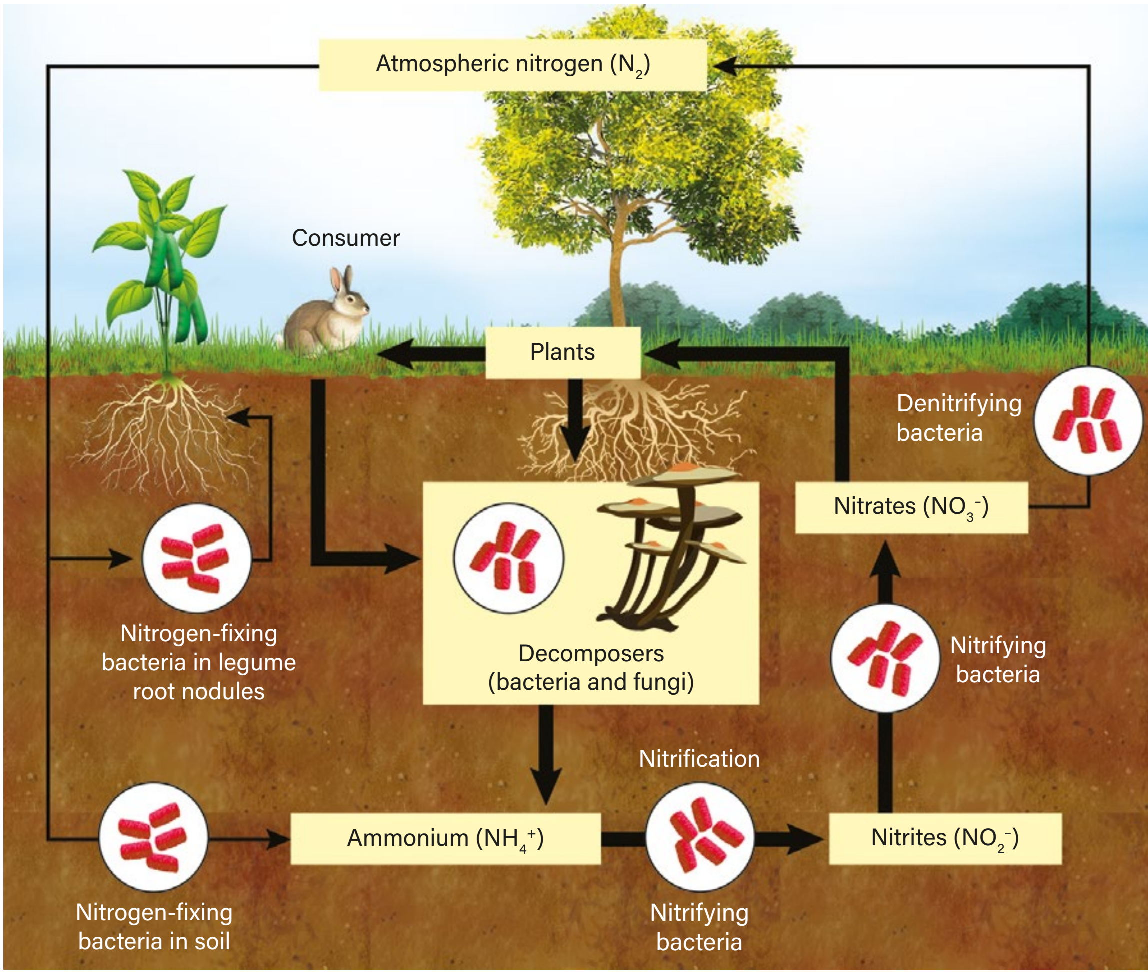


Figure 3.11: The nitrogen cycle is crucial for plants to grow.

Learning Ladder

Ecosystems

1. Identify the two types of organisms that are important for the nitrogen cycle. Suggest what role they each play.
2. Summarise the stages of the nitrogen cycle, using Figure 3.11 to assist you.
3. Explain what is meant by a 'matter cycle'. Use specific diagrams and examples in your response.

Use and influence of science

1. Consider an ecosystem that becomes too cold for bacteria to survive. Propose whether this is an environmental, economic or social issue.
2. Describe how society might be affected by the scenario in Question 1.

Communicating

p. 245

1. Identify and define four scientific terms used in this section that are not listed as key terms.
2. Propose why Figure 3.11 is a useful way to communicate ideas about the nitrogen cycle.
3. Construct a series of comic strips to outline the main steps of the nitrogen cycle as shown in Figure 3.11.
4. Prepare a digital poster based on Figure 3.11, annotated with additional information about the nitrogen cycle.
5. Share your digital poster with a classmate. Discuss the similarities and differences between your poster and theirs. Identify which poster would be most suitable for an adult audience.

Key idea: Form and function

Identify and explain a process that allows different forms of carbon, oxygen and hydrogen to cycle through ecosystems. Use an annotated diagram to support your explanation.

Success criteria

- I can outline a specific example of how matter is cycled through ecosystems (for example, nitrogen).
- I can discuss why it is important that a variety of elements are cycled through ecosystems.

3.5 ▸ Energy flows through ecosystems

Learning intention

At the end of this lesson, I will be able to use food webs to model how energy flows through ecosystems.

Key terms

energy pyramid: a model that shows the flow of energy from one trophic level to the next

food chain: a path of energy through an ecosystem

food web: a system of interlocking food chains

trophic level: the position of an organism in a food chain

Investigation 3.5

Algal balls, p. 297

Key idea: Form and function

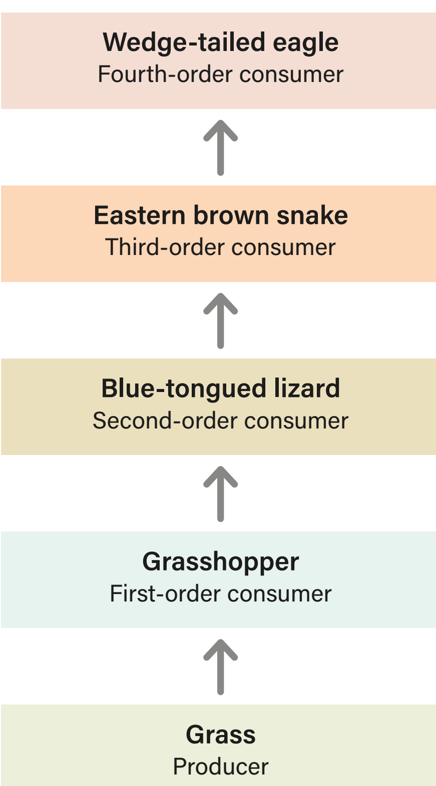


Figure 3.12: Each organism in a food chain provides energy for the next organism. Organisms can be described according to their position in the chain.

All living organisms need energy to grow, repair damage and reproduce. Energy enters most ecosystems as solar energy from the Sun and is transferred through food chains and food webs.

Plants bring energy into ecosystems

Producers convert light energy from the Sun into chemical energy during photosynthesis. In photosynthesis, plants use light energy to produce glucose ($C_6H_{12}O_6$) from carbon dioxide (CO_2) and water (H_2O).

Food chains show the path of energy

Food chains are diagrams that show one possible pathway of energy through an ecosystem. Energy is transferred between organisms when they eat or are eaten. Food chains always begin with a producer: a plant or microorganism that can produce energy. Food chains have arrows between each organism to show the direction that energy moves. In an Australian grassland ecosystem, a grasshopper gains energy from grass, so there is an arrow from the grass to the grasshopper (see Figure 3.12).

The other organisms in the food chain are consumers. Consumers can be described in terms of the organisms they feed on (see Table 3.2). The different types of consumers help maintain balance in ecosystems.

Table 3.2: Types of consumers and how they obtain their energy

Consumer	Obtains energy by ...	Examples
Herbivore	feeding on producers	Koala, grasshopper
Omnivore	feeding on producers and consumers	Sea star, most humans
Carnivore	feeding on other consumers	Kookaburra, brown snake
Decomposer	breaking down dead matter	Bacteria, fungi

Food chains interact to form food webs

Organisms are usually part of more than one food chain because they have more than one food source or get eaten by more than one consumer. A species needs multiple food sources in case one runs out.

Food webs show all the feeding relationships in an ecosystem. They show a much bigger picture of the flow of energy and of how each organism is involved. Food webs also show how organisms are arranged into different **trophic levels**. Producers are at the bottom and the highest-order consumer is at the top. Energy passes from low trophic levels to the higher trophic levels through consumption.

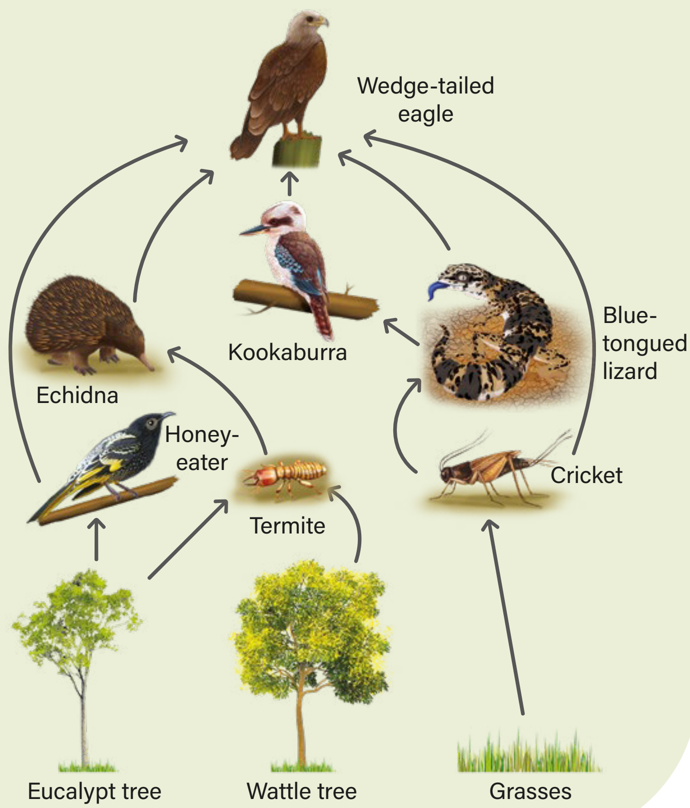


Figure 3.13: This bushland food web shows how different food chains can connect.

Energy is lost at each trophic level

Only about 10 per cent of the energy in a trophic level is passed on to the level above. This is why it requires many producers and lower-level consumers to support a small number of higher-order consumers. This relationship can be represented in an **energy pyramid** (see Figure 3.14). The energy pyramid shows how energy is lost to the surroundings between each trophic level of the food web.

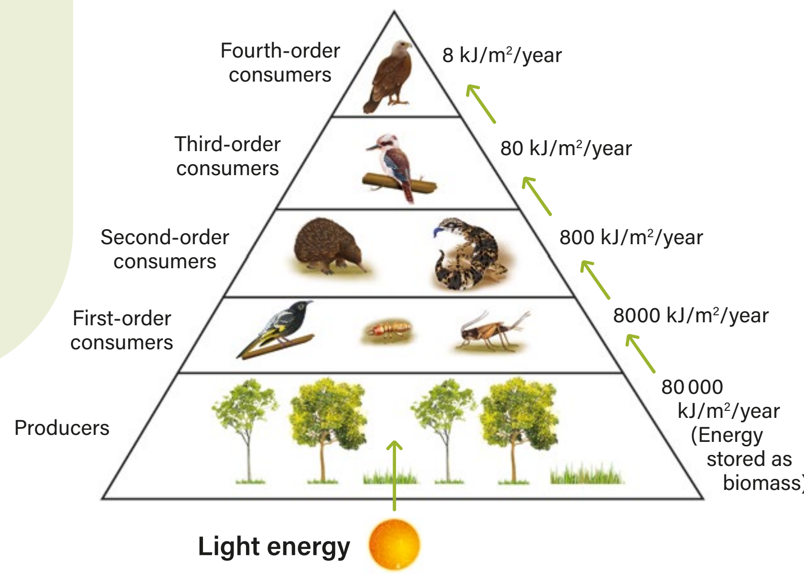


Figure 3.14: An energy pyramid shows the flow of energy from one trophic level to the next.

Learning Ladder

Ecosystems

1. Identify the main source of energy in any ecosystem. Describe how it enters the first level.
2. Describe what arrows in a food chain or web represent.
3. Explain how a food web can be used.
4. Select an organism from Figure 3.13. If it were removed, predict the impact on the other organisms in the food web. Provide specific reasons.
5. Analyse and discuss how ecosystems might respond to more frequent flooding.

Use and influence of science

1. Identify a social issue related to tourism in local habitats.
2. Boat ramps are sometimes closed when seals visit Port Phillip Bay. Propose a scientific reason for this.
3. Propose and explain how extreme weather events might impact scientists' ability to investigate food webs.

Processing, modelling and analysing *p. 230*

1. Select an organism from the food web in Figure 3.13. Identify the food chain or chains to which it belongs.
2. **a** Construct a table to collect information about the ecosystems in your garden. Include consumers and producers, where they get their energy, what level of consumer they may be, and any other facts.
   b Propose one food chain for your ecosystem.
3. Construct a column graph to represent Figure 3.14. Show the amount of energy transferred to each trophic level, assuming the producers begin with 80 000 kJ. (*Hint:* Put energy (kJ) on the vertical (*y*) axis.) See the Science how-to section on page 272 if you need help.

Key idea: Form and function

If an invasive species were introduced into a food web, describe the effect on other organisms and the energy flow.

Success criteria

- I can identify where energy in a food web comes from.
- I can describe the role of food webs in modelling how energy flows through an ecosystem.

3.6 ► Human impacts on ecosystems

Figure 3.15: Algal blooms prevent light from penetrating to deeper water, which means producers cannot photosynthesise and support food webs.

Learning intention

At the end of this lesson, I will be able to describe how ecosystems can be affected by human impacts.

Key terms

biodiversity: the variety of organisms in an ecosystem

endangered: at risk of becoming extinct

extinct: having no living members of the species; died out

non-biodegradable: does not break down in the environment

pesticide: a chemical used to kill insects or other organisms that feed on plants

threatened: likely to become endangered in the near future

Key idea: Form and function

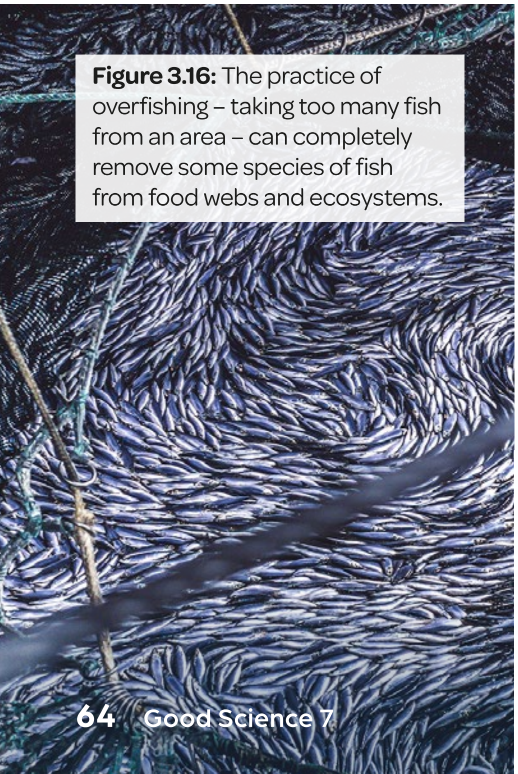


Figure 3.16: The practice of overfishing – taking too many fish from an area – can completely remove some species of fish from food webs and ecosystems.

Everything within an ecosystem is linked. Therefore, if one thing changes, so will other things change. Changes can happen to the biotic factors or the abiotic factors. Many human activities have dramatic impacts on the feeding relationships in an ecosystem.

Farming, fossil fuels and plastics can damage the environment

Pesticides are chemicals farmers use to kill unwanted plants and insects as a way to protect their crops. These chemicals may be passed on to animals that eat the pests. The chemicals can build up to toxic levels in the ecosystem and harm organisms (including humans) that consume the pesticides in their food.

Algal blooms happen when large amounts of nutrients from farms or industry run off into streams. The algae thrive on the extra nutrients and grow quickly, forming a bloom that covers the surface of the water. The bloom prevents light reaching the producers below, which die and so cannot support the rest of the food chain.

The burning of fossil fuels is a cause of global warming, which has a big impact on habitat and food sources in food webs. Fossil fuels are also used to make plastics, which are **non-biodegradable**. They can enter food webs when animals accidentally consume them.

Removing or introducing organisms affects biodiversity

Biodiversity is the variety of species within an ecosystem. In an ecosystem with high biodiversity, there are more species in a food web, so there are more food chains and a larger variety of food sources. Thus, species in a biodiverse ecosystem have more chance of survival if the environment changes.

Introduced species – such as cane toads and blackberries – often thrive and take over, reducing biodiversity. In some cases, this has led to species becoming **extinct**. The Australian Government is committed to supporting the recovery of any **threatened** species.

Keystone species are essential to ecosystems

A keystone species has an irreplaceable role in its ecosystem. No other species in its ecosystem can fill its niche. If a keystone species is removed, the whole ecosystem can collapse.

Southern cassowaries (*Casuarius casuarius johnsonii*) are a keystone species in the North Queensland tropical rainforest ecosystem. They eat fruit and then deposit the seeds in their dung. Without cassowaries, some rainforest plants could become extinct.

Southern cassowaries are **endangered** because of habitat destruction and other human activities. Recent conservation efforts such as habitat protection and restoration have helped to reverse the population decline. However, cassowaries are still being killed by traffic, dogs and feral pigs.

Figure 3.17 shows the predicted changes to the population of cassowaries if different conservation strategies are used. In 2015, the Threatened Species Strategy was implemented. No clear improvements were seen in the following three years, but conservationists are hopeful that the revised Threatened Species Action Plan (2022–32) will result in an increase in cassowary numbers. Increasing the area of rehabilitated rainforests is an obvious way to increase the cassowary population.

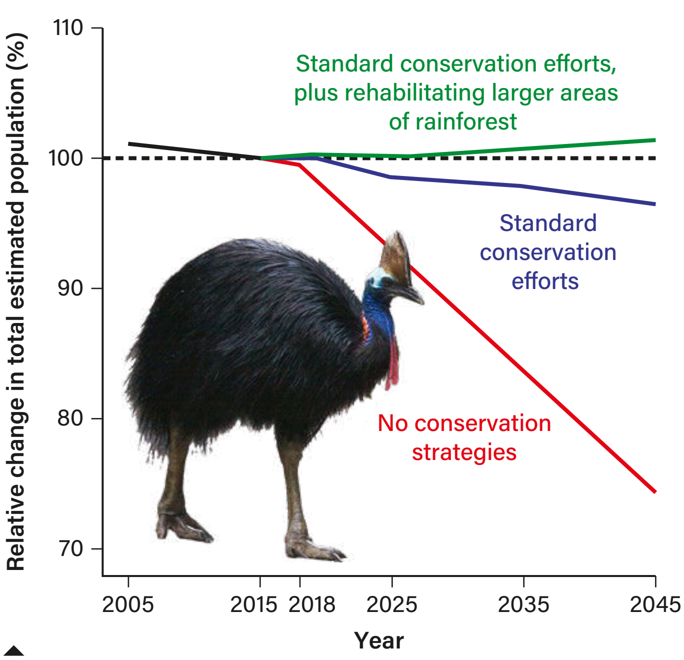


Figure 3.17: Predicted responses to management scenarios of the southern cassowary

Learning Ladder

Ecosystems

1. List four human activities that affect ecosystems.
2. Describe the effects of algal blooms on food webs.
3. Explain why organisms are more likely to survive in an ecosystem that has high biodiversity.
4. Discuss which has higher biodiversity: a tropical rainforest or a wheat farm. Provide a reason.

Use and influence of science

1. Classify the human activities from Question 1 under 'Ecosystems' above as environmental, ethical, social or economic issues.
2. Select one human activity and describe how learning more about its scientific impact might affect society.
3. Outline the economic impacts of taking extreme measures to conserve keystone species.

Processing, modelling and analysing p. 230

Refer to Figure 3.17.

1. **a** Identify which management strategy has the most positive effect on the cassowary population.
   b What percentage decline in population will be seen from 2025 to 2045 with no conservation?
2. Imagine you know the number of cassowary sightings by park rangers, residents and tourists in each month of the past year. Construct a table to organise the data.
3. Compare the three types of conservation efforts.
   a How many times more effective are the standard conservation efforts (blue) than doing nothing (red)? Use the y-axis for scale.
   b How many times more effective are the rehabilitation efforts (green) than just the standard efforts (blue)?
4. Identify and discuss the trend in the 'Standard conservation plus rehabilitation efforts' data (green).
5. Discuss the anomaly seen in the 'Standard conservation efforts' (blue) trend between 2025 to 2035, as compared to the years before and after.

Key idea: Form and function

Choose an aspect of agriculture that has a negative impact on the form and/or function of ecosystems. Discuss ways to minimise or compensate for the impact.

Success criteria

- I can propose how human activity can affect interactions within food webs and chains.
- I can identify examples of human activities that impact natural Australian environments.

3·7 ▸ Impacts of natural events on ecosystems

Learning intention

At the end of this lesson, I will be able to describe ways that ecosystems can be affected by environmental factors.

Key terms

germination: the process in which previously dormant seeds put out shoots for new growth

intensity: how much heat is released from a fire front

understorey: ground-level vegetation

Key idea: Form and function

Figure 3.18: Lightning strikes can cause natural bushfires.

Figure 3.19: Ecosystems are not able to recover easily after high-intensity bushfires.

Australian ecosystems are often harmed by unpredictable natural events that reduce biodiversity, such as droughts, floods and bushfires. However, some natural events – for example, low-intensity bushfires and seasonal migration – can trigger new growth and cause other beneficial changes in an ecosystem.

Low-intensity bushfires are helpful in some ecosystems

Bushfires are common natural events in Australia due to the hot, dry summers of many regions. Lightning strikes are the most common natural cause of bushfires. When lightning hits a dry or dead tree, the heat of the strike makes the tree catch fire and break apart. Burning wood scatters and ignites other plants. The **intensity** and duration of a bushfire depend on the plants in the ecosystem, because they provide the fuel needed for the bushfire to burn.

Low-intensity bushfires usually do not last very long and do not destroy many plants. In fact, they can be helpful for some ecosystems because the fires remove dead or older plants, making more space for young plants to grow. Fire can even trigger **germination** in some plants. The ash from the fire returns some nutrients to the soil, and the ecosystem recovers relatively quickly. Controlled burns are part of fire safety, and lighting low-intensity bushfires has been a practice of First Nations Peoples for thousands of years.

High-intensity bushfires usually harm ecosystems

High-intensity bushfires damage ecosystems. Tall, thick and compact grasses and **understorey** plants provide a large fuel supply, so high-intensity bushfires are more likely to happen in areas where there has not been a fire for many years. In this case, there is a large amount of dry plant material, such as fallen branches and dead trees, at the ground layer. This results in high-intensity fires that burn for a long time and can destroy entire trees and huge numbers of animals. The loss of plants and animals has a lasting negative impact on the entire ecosystem.

Technology can help scientists monitor bushfires and learn from previous fires. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) has a bushfire research facility in Canberra called the Pyrotron. There, scientists safely carry out bushfire experiments. The Pyrotron is a 25-metre-long wind tunnel that uses fuel sources such as leaves that are set on fire while a fan blows air through the tunnel. Sensors and cameras measure how the fire spreads, while observers watch through fireproof windows.

Computer models can also be used to predict the movement, intensity and duration of a bushfire. The CSIRO's bushfire modelling system, Spark, simulates a bushfire. It uses the information it receives to predict the direction, speed and intensity of a bushfire.

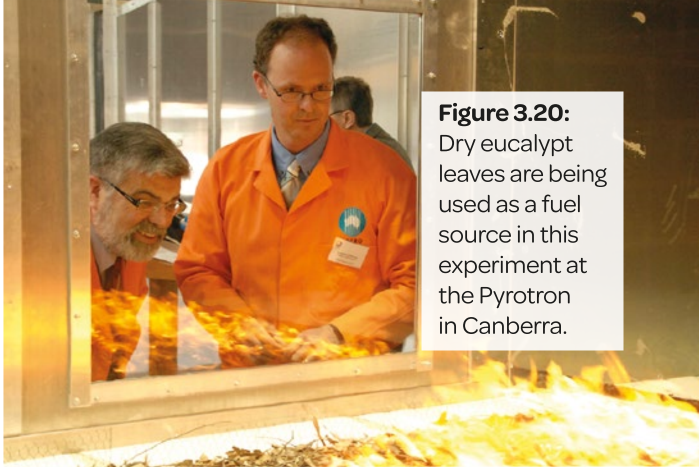


Figure 3.20: Dry eucalypt leaves are being used as a fuel source in this experiment at the Pyrotron in Canberra.

Seasonal migration affects ecosystems

Seasonal migration affects ecosystems by changing the number of animals in different areas throughout the year. Animals that migrate move to places where food is plentiful or where it is easier to mate and reproduce. When migratory animals arrive in new ecosystems, local animals might have to compete for food, water or shelter. When the migratory animals leave, the food chain can be disrupted because predators or prey might be missing. Migrating animals also carry nutrients, like seeds or waste, between ecosystems, helping plants to grow in new places. Events such as bushfires can destroy habitats, forcing animals to migrate earlier or to different areas, which can further disrupt ecosystems and make them less stable.

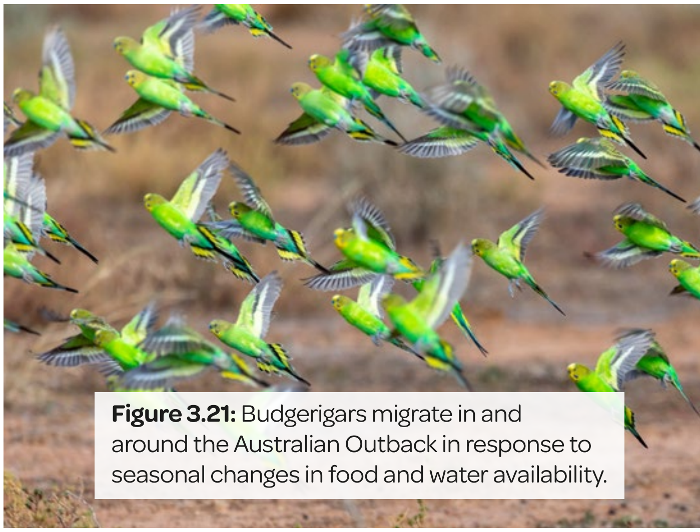


Figure 3.21: Budgerigars migrate in and around the Australian Outback in response to seasonal changes in food and water availability.

Learning Ladder

Ecosystems

1. Identify at least three types of natural events that cause changes to living ecosystems.
2. Describe the benefits of low-intensity fires.
3. Explain the benefits and drawbacks of seasonal migration.
4. Propose what plant characteristics you would see in an ecosystem that is prone to low-intensity bushfires. Discuss ways to promote these characteristics.
5. Use the internet to investigate ways that ecosystems are impacted by and respond to seasonal migration.

Use and influence of science

1. Propose the socio-economic issue that is most closely impacted by:
   a low-intensity bushfires. **b** high-intensity bushfires.
2. Describe how bushfire research conducted at the CSIRO affects society.
3. Propose and explain how the study of migratory birds might impact the birds' environment and therefore pose ethical issues.
4. Discuss the environmental benefits of scientists using modelling to better understand the behaviour of bushfires.
5. Evaluate whether advertisements about the importance of bushfire plans are linked to the communication of scientific knowledge based on government viewpoints and policy.

Evaluating

p. 239

1. Propose an assumption scientists make when using the Pyrotron to simulate bushfires.
2. The wind in the Pyrotron tunnel may be less intense than in nature. Identify this as a random or a systematic error. Explain your response.

Key idea: Form and function

Propose and discuss an aspect of seasonal migration that has a negative impact on the form and/or function of ecosystems. In your response, refer to flow of matter (form) and energy (function).

Success criteria

- I can name at least three natural events that cause environmental change to Australian ecosystems.
- I can describe changes that could occur in an ecosystem after a natural event such as a bushfire.

3·8 ▶ First Nations Peoples' management of ecosystems

Learning intention

At the end of this lesson, I will be able to describe how land management practices of Aboriginal and Torres Strait Islander Peoples can help to inform sustainable management of the environment.

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

Key idea: Form and function

Before colonisation, First Nations Peoples managed the landscapes and waterscapes to ensure there was enough nourishing food for the present and into the future.

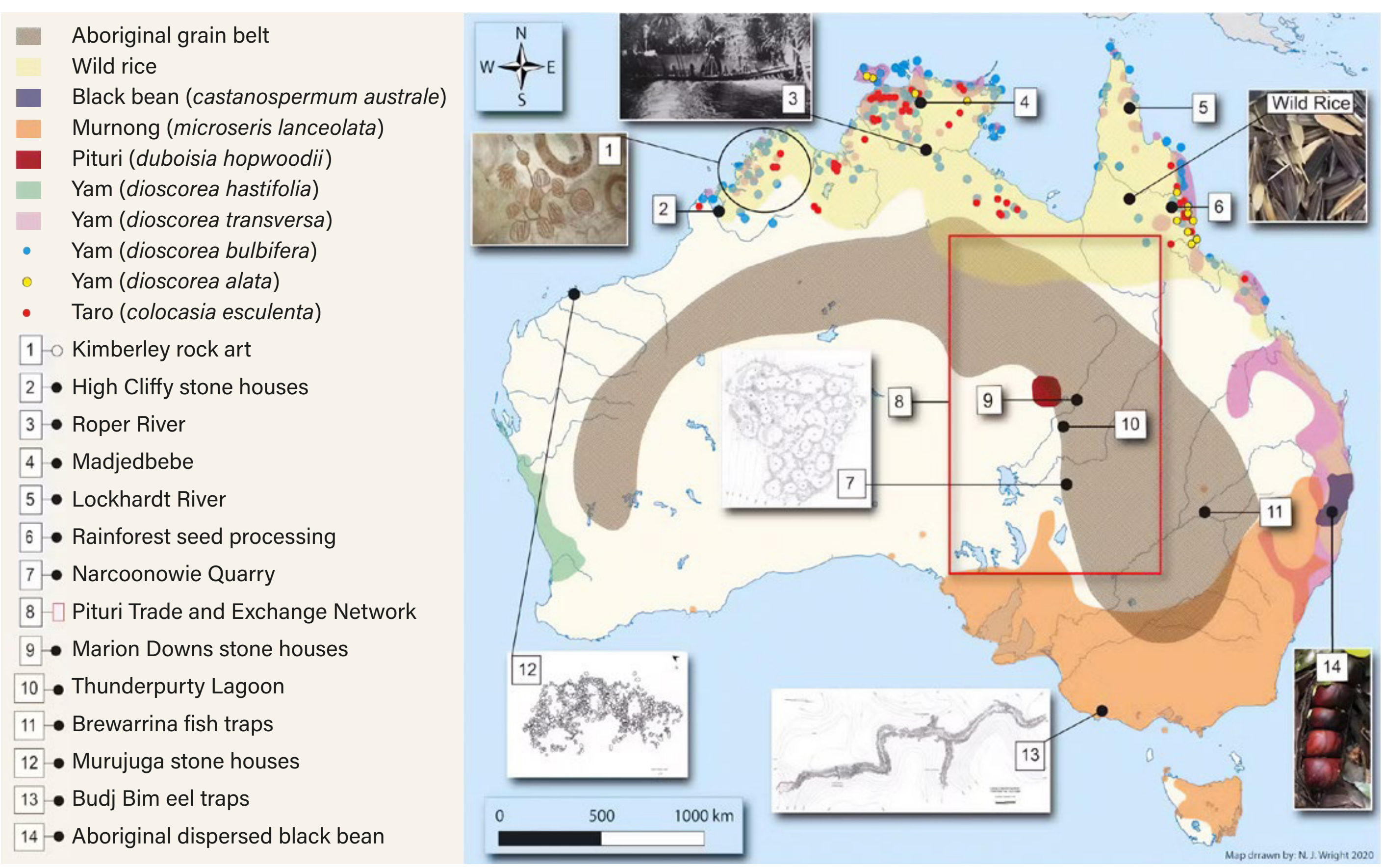
Caring for Country and ecosystem health

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 scientific knowledges that have informed the specific practices of caring for Country have been taught through story, song and dance.

First Nations agriculture

Aboriginal farmers farmed Murnong (yam daisy) **tubers** sustainably for thousands of years across the south-eastern part of the Australian continent.

Figure 3.22: The areas where farming and agriculture flourished across the Australian continent before European colonisation.



Aboriginal sustainable practices included:

- allowing enough plants to go to seed to sustain future harvests
- tilling 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.

After European colonisation, the Murnong was brought to the brink of extinction by introduced livestock, which compacted the soil and ate its leaves.

First Nations Peoples built stone weirs 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.

First Nations 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.

First Nations fire management

First Nations Peoples have long used various fire management practices to help manage the landscape. Periodically conducting low- or high-intensity burns prevented major bushfires by removing dead leaves, fallen trees and other debris. Managed burns also modified soil nutrients to favour specific plants and prevent weeds, sustaining open forested areas that supported diverse plant and animal life. Without these fire management practices, major bushfires can develop.

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.

In Section 3.9, you will see how traditional cultural burning is being used to rejuvenate the land and protect endangered native species like the Leadbeater's possum.

Learning Ladder

Ecosystems

1. Identify how First Nations Peoples knew when not to harvest freshwater crustaceans.
2. Describe the changes to the ecosystem that nearly caused the Murnong to become extinct.
3. Construct a flowchart to represent First Nations Peoples' understanding of breeding and migration cycles in aquaculture.
4. Explain how stories help to create links between plants and aquatic animals.
5. Discuss why First Nations land management practices include regular burning of areas of vegetation.

Nature and development of science

1. Identify a problem involving the Murnong that science helped to solve.
2. Describe how the inclusion of First Nations rangers in managing ecosystems is changing how science is being used.
3. Explain a method First Nations Peoples have used for millennia to teach science.

Processing, modelling and analysing p. 230

1. Examine Figure 3.22.
   a Identify the state where Budj Bim is located.
   b Identify how many different species of yam are represented in the diagram.
   c Identify the food source grown in the pink area.
2. Construct a table or chart to organise your information from Question 1.

Key idea: Form and function

Research why the Murnong nearly became extinct. Discuss the factors that contributed to its near extinction. What could help to revive this plant?

Success criteria

- I can describe how land management practices of Aboriginal and Torres Strait Islander Peoples can help to inform sustainable management of the environment.

3·9 ▸ Australian ecosystems at risk

Learning intention

At the end of this lesson, I will be able to describe the link between urbanisation and deforestation, and how it contributes to the decline of species populations.

Key terms

deforestation: the removal of trees to make land available for other uses

endemic: only found in a certain location or community

fauna: animals

flora: plants and microorganisms

urbanisation: the creation of urban areas such as cities

Key idea: Form and function

Australia has **flora** and **fauna** that is unique in the world. Almost half of all species in Australia are **endemic**. This is what makes them so distinct but also vulnerable to extinction. Australia faces one of the world's most pronounced declines in flora and fauna populations.

Australia has the world's highest mammal extinction rate

Small mammals are particularly vulnerable because for millions of years they had no major predators and little competition. This means they are not equipped to cope with major changes in their ecosystems.

Figure 3.24 shows that extinction rates have steadily increased. They are now the highest in the world. The main reasons for the decline in biodiversity are introduced species such as rabbits, foxes and cane toads, and habitat destruction.

Introduced species compete with native species

Introduced species compete with native species for the same resources, remove species through predation or toxins, and even damage soils and plant life through trampling, burrowing and digging.

In Australia, most ecosystems have been affected by introduced species. Foxes and cats are skilled predators and have hunted many species to extinction. Rabbits out-compete small marsupials. Cane toads (and their tadpoles) are toxic if eaten by native mammals for food. Brumbies (feral horses) and camels trample fragile soils and plants that have not evolved to cope with hard-hooved animals. Each introduced species was brought to Australia for specific reasons, but the Europeans lacked knowledge about Australian ecosystems and did not foresee the damage the introductions would cause.

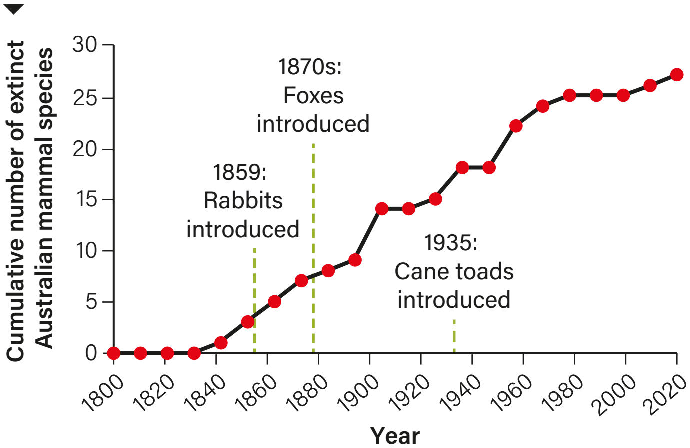
Figure 3.23: The natural habit of the Leadbeater's possum has been so depleted, the species is in danger of becoming extinct.

The Leadbeater's possum

The Leadbeater's possum is a critically endangered species native to Victoria. The old mountain ash forests that are the natural habitat of these possums have been depleted by bushfires and unsustainable logging. Only these old-growth trees have the hollows in their trunks and branches that the possums use to make their homes. The Black Saturday bushfires of 2009 destroyed almost half of the possums' limited habitat, pushing them further towards extinction.

In 2019, the Dja Dja Wurrung Clans Aboriginal Corporation reintroduced traditional burning practices in Central Victoria to reduce the risk of high-intensity fires that threaten the habitats of species like the Leadbeater's possum.

Figure 3.24: Total number of extinctions of endemic mammal species, 1800–2020



Urbanisation and deforestation damage food webs

Urbanisation is the replacement of natural ecosystems with cities and suburbs. As cities grow, the surrounding land is cleared and many of the organisms in the ecosystem die.

Deforestation is the removal of large trees to make space for towns and farms. All organisms within food webs are affected by deforestation because they all depend on the original energy source from these producers. Removing trees can increase soil erosion and water pollution. This is because tree roots hold the soil together and filter the water flowing through the ecosystem. Without trees, erosion can increase as wind and rain carry away the topsoil needed for plants to grow.

To safeguard Australia's unique natural heritage for future generations, we need to address the causes of biodiversity loss.

Figure 3.25: The land covered by this housing development once had large trees and an ecosystem suited to a variety of organisms.

Learning Ladder

Ecosystems

1. List the main factors that contribute to species population decline in Australia.
2. Define the terms 'urbanisation' and 'deforestation'.
3. Explain, using examples, how urbanisation can affect interactions in food chains and food webs.
4. Compare the effects of urbanisation and introduced species. Suggest which factor you think will have the biggest impact on extinct species rates in Australia. Justify your response.

Nature and development of science

1. Propose a solution for the negative impact that urbanisation has on ecosystems.
2. Describe how engineers and ecologists could work together to solve problems related to urbanisation.

Communicating

p. 245

1. List and define any scientific terms in this section that are not already listed as a key term.
2. Imagine you are upset about the lack of conservation efforts in your community. Describe an appropriate way to communicate your frustrations to the local council.
3. To support your argument to the local council, propose three websites that provide reliable statistics about animal populations in the area.
4. Propose two digital platforms that could be used to communicate your findings.
5. Construct an evidence-based presentation for the local council, encouraging them to improve conservation efforts.

Key idea: Form and function

Construct a comic strip that highlights physical habitats in natural environments, and how they can be impacted by urbanisation and deforestation. Include examples of how animal functions may also be affected.

Success criteria

- I can describe the link between urbanisation and deforestation and how it contributes to the decline of species populations.
- I can explain the impact of introduced species on interactions in ecosystems.

3.10 ▶ Key idea: Form and function – impact of agriculture on ecosystems

Learning intention

At the end of this lesson, I will be able to describe how agricultural practices impact the function of surrounding ecosystems.

Key terms

agriculture: the science or practice of farming

cultivation: preparing and using land for crops or gardening

form: what something is made up of

function: the way something works

irrigation: supplying water to land or crops

monoculture: the practice of cultivating a single crop in a given area

selective breeding: breeding organisms with desirable traits

yield: the amount of something that is harvested

Key idea: Form and function

Figure 3.26: Planting canola seeds into soil without ploughing after the harvest causes less erosion.

Farming crops for food production is called **cultivation**. This is part of the practice of **agriculture**, where farmers use land to grow crops and to breed animals for food and other products. Different parts, or **forms**, of agriculture can have negative impacts on how ecosystems **function**. Scientists work with farmers and governments to come up with forms of cultivation that improve crop yields and cause less harm to the healthy functioning of ecosystems.

Monocultures can lead to a loss of biodiversity

Some forms of farming include growing only a single crop, such as canola or wheat, that covers a very large area of land. These crops are called **monocultures** – other species are removed so that they do not compete for nutrients or feed on the crop. One functional problem with this loss of biodiversity is that if a disease or pest affects one plant in a monoculture, it can damage all of them because they are all the same.

After a crop is harvested, the soil is ploughed (turned over) to remove the remaining roots of the crop from the soil. This increases seed germination and removes weeds, but it also increases soil erosion and removes nutrients stored in decomposing plants.

Many farmers are starting to use agricultural methods that allow nutrients to remain in the soil. If forms of plant matter are left in the soil, without being ploughed, they decompose, leaving carbon and other nutrients in the soil. This reduces the amount of fertiliser that may be required for optimal functioning and may be a cheaper form of farming.

Chemicals can build up in ecosystems

To give better **yields**, crops need nutrients. Traditionally, forms of chemical fertilisers have been added to the soil, but fertiliser runs into waterways when there is heavy rain or when too much is used. This affects the functioning of other ecosystems; for example, it can cause toxic algal blooms.

Pesticides and herbicides are used in agriculture to remove pests and weeds from crops. These chemicals, too, can build up in ecosystems, affect other organisms and enter waterways. They can be passed along food chains and cause harm to other organisms.

Reducing and improving chemical use is important in agriculture. Organic fertilisers such as compost and manure add nutrients without causing the same harm as chemical forms of fertilisers.

Irrigating crops uses large amounts of water

Traditional sprinklers used in agriculture for **irrigation** waste a lot of water – some of the water evaporates or does not reach the plant, so a large amount needs to be used to soak into the soil. Micro-irrigation systems are replacing some of these irrigation sprayers. The water pipes sit just above the crops and allow water to drip slowly on the plants.

Scientists also use scheduling tools to work out the best time to irrigate a particular crop based on rain forecasts, plant stress and temperature. This gives better plant growth and prevents water from being wasted when irrigation is not needed.

Selective breeding is used to develop new crops

Some scientists study different species of crop to increase yield and find varieties that can resist drought, pests and diseases. This can be done as part of **selective breeding** programs. When a disease destroys a crop, a few plants usually survive because they are naturally resistant. Scientists can then breed more of those plants to create an entire crop that is formed to be resistant to the disease.

Blackleg is a fungus that damages canola crops in New South Wales and Victoria. Farmers usually use chemical sprays to kill and prevent the spread of blackleg, but the chemicals also affect the functioning of nearby ecosystems. Scientists have studied varieties of canola that can resist blackleg. Growing these varieties of canola is the best way to control the effects of blackleg in Australia.

Figure 3.28: Depending on the form of agricultural practice, surrounding ecosystems can maintain healthy functioning.

Figure 3.27: Micro-irrigation systems are replacing traditional spraying methods for some crops.

Learning Ladder

Ecosystems

1. Give two examples of crops grown in Australia.
2. Describe the process and purpose of selective breeding.
3. Propose, using diagrams, how traditional methods of irrigation could impact local food chains.
4. Predict how using chemical pesticides and herbicides can interrupt the cycle of matter and energy through ecosystems.

Use and influence of science

1. Propose an example of each of the following socio-scientific issues created by the agriculture industry.
   - **a** Ethical
   - **b** Environmental
   - **c** Social
   - **d** Economic
2. Describe an example of how scientific knowledge has influenced agriculture.

Evaluating

p. 239

You are asked to conduct an investigation to determine which type of organic fertiliser works best.

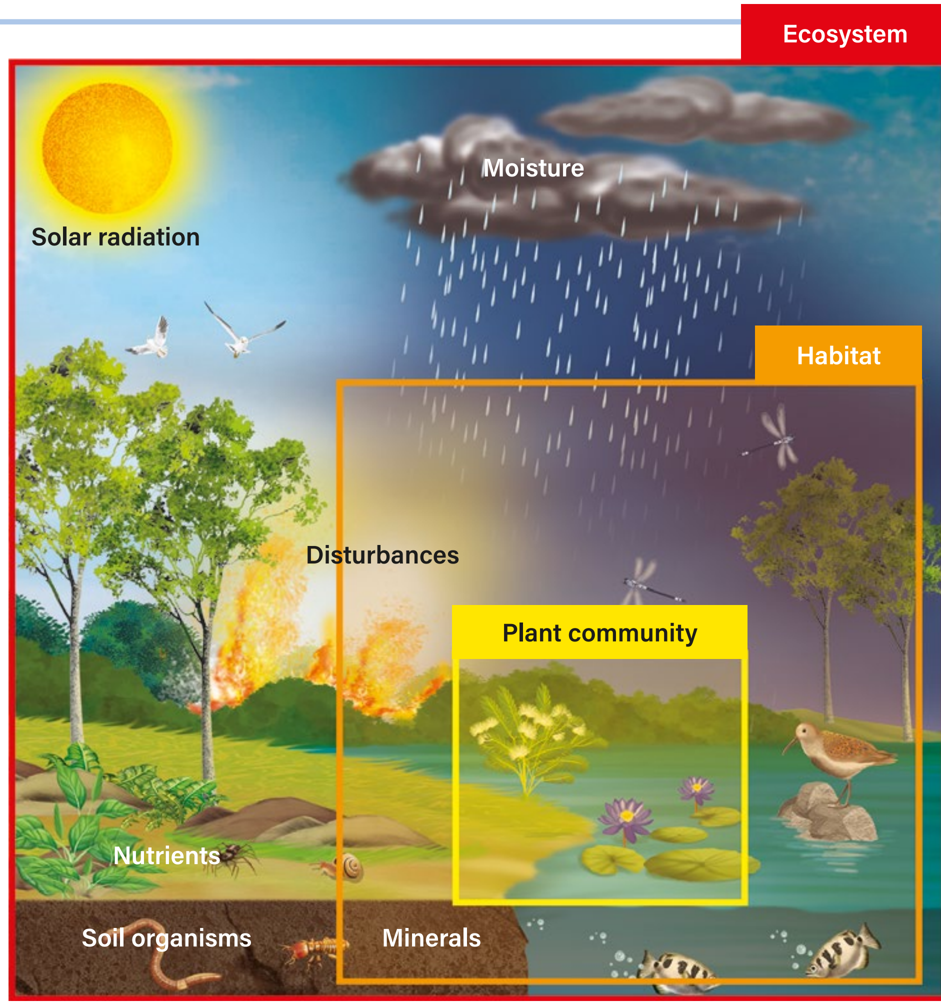
1. Identify one assumption you might make as the investigator.
2. You do not measure the initial height of the plants. Describe the type of error this presents when measuring the final height of the plants.
3. Conduct a search about the effectiveness of organic fertilisers. Construct an appropriate reference to acknowledge the source. Refer to the Referencing How-to section on page 258.
4. Outline the important information that will be required when justifying your conclusions about organic fertiliser.
5. Evaluate the following statement: 'Seaweed-based organic fertilisers must be the best because they are the most expensive'.

Success criteria

- I can describe two different forms of agriculture.
- I can explain how the functioning of ecosystems can be impacted by agricultural practices.

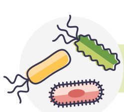
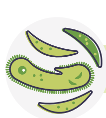
Summary

- An **ecosystem** is an area that contains living things and their environment.
- A **community** is all the living things in an ecosystem that rely on each other to survive and interact in different ways.
- A **habitat** is the natural environment where a species or an organism lives that supplies food, water, shelter and protection, and enables reproduction.
- **Matter** cycles through different parts of ecosystems, including the atmosphere, soil and different organisms.
- **Energy** enters most ecosystems as solar energy from the Sun.



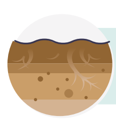
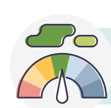
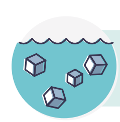
Biotic factors

The living things in an ecosystem are referred to as **biotic** factors.

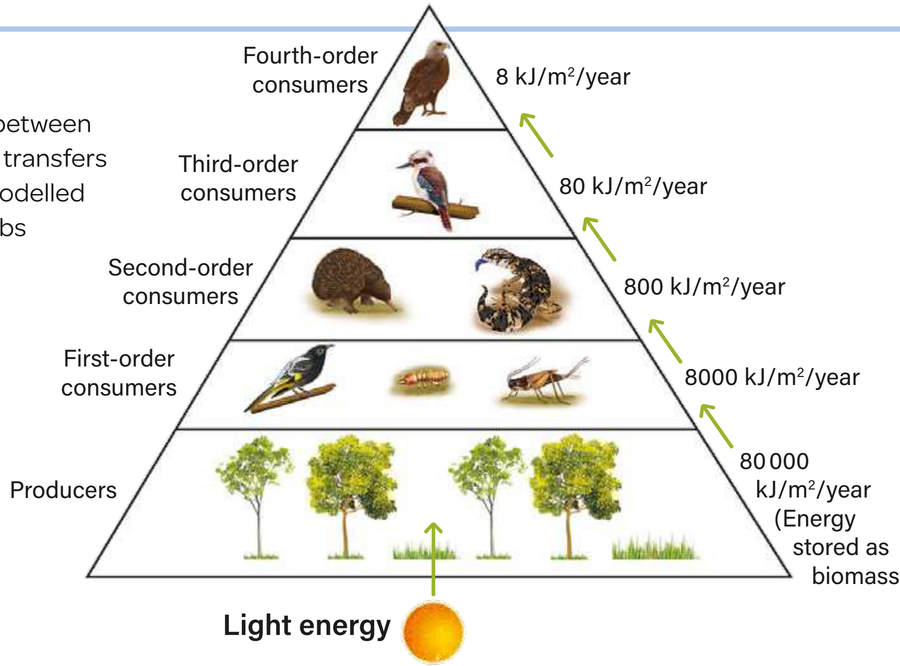
 Bacteria
 Fungi
 Plants
 Archaea
 Animals
 Protists

Abiotic factors

The non-living things, such as soil and water, are known as **abiotic** factors.

 Rainfall and water availability
 Soil type
 Temperature
 PH of soil or water
 Sunlight
 Nutrient availability in soil or water
 Gas (oxygen and carbon dioxide) availability
 Salinity (saltiness) of soil or water

- The feeding relationships between organisms, and the energy transfers in an ecosystem, can be modelled using food chains, food webs and energy pyramids.
- Human activities such as farming, the use of fossil fuels, and the removal or introduction of species can have dramatic impacts on the feeding relationships in an ecosystem.
- Natural events such as bushfires and seasonal migration can have an impact on ecosystems and biodiversity.
- Australia has some of the world's highest rates of species population decline and extinction due to increased vulnerability to introduced species, urbanisation and deforestation.
- Many projects today are re-engaging with First Nations knowledge of sustainable harvesting practices.



Key idea: Form and function

- Different aspects, or forms, of agriculture can impact the functioning of ecosystems in different ways.
- Scientists work with farmers and governments to come up with forms of cultivation that improve crop yields and cause less harm to the functioning of surrounding ecosystems.

Masterclass

Steps in progression

		1	2
Science understanding	**Ecosystems**	Identify three land-dwelling apex predators.	Describe what an apex predator is, using an example.
Science as a human endeavour	**Nature and development of science**	Propose whether it would be a problem if there were no apex predators in an ecosystem.	Describe two branches of science that might be interested in learning about apex predators.
Science as a human endeavour	**Use and influence of science**	Identify an ethical issue related to studying apex predators in their natural habitat.	Propose how understanding the role of apex predators in ecosystems affects society.
Science inquiry skills	**Processing, modelling and analysing** See Table 3.3.	Categorise the apex predators listed in Table 3.3 into three categories based on their life spans.	Construct a new table to organise the categories you identified in step 1.
Science inquiry skills	**Evaluating**	Identify an assumption that is made in Table 3.3.	Describe an error that exists due to using a stopwatch to measure time to calculate maximum speed.
Science inquiry skills	**Communicating**	Identify two pieces of scientific information about the orca and the grey wolf.	Describe how you might communicate information about the average life span of apex predators.

From body forms to physical function

What do body forms have to do with physical functioning, both individually and as part of an ecosystem? Is there a relationship between the organisms at each trophic level of ecosystems (that is, at each position within the food chain) and how their body forms operate? Consider that plants – the producers – are at the bottom of the food chain, and their organ formations are significantly simpler than animals' body forms.

Let us now consider some of the animals that occupy the highest trophic level of ecosystems throughout the world. According to Table 3.3, life span is not something that apex predators have in common. However, to be an effective predator, we assume these animals have body formations that make them fast and strong. Bones, muscles and joints provide animals with the strength and agility required to hunt, chase and capture prey. Could these combined components working together as a system be what sets them apart from other organisms in their ecosystems? Or maybe the status of these animals as apex predators is unrelated to their physical features. Perhaps their excellent predator skills come from structural, behavioural and/or physiological adaptations?

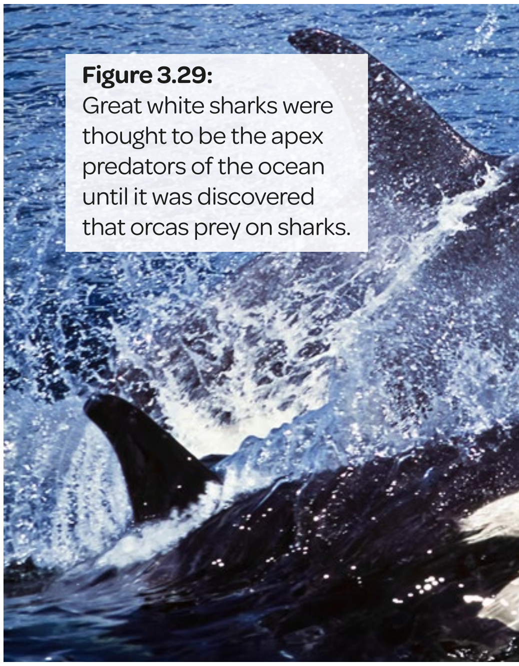


Figure 3.29: Great white sharks were thought to be the apex predators of the ocean until it was discovered that orcas prey on sharks.

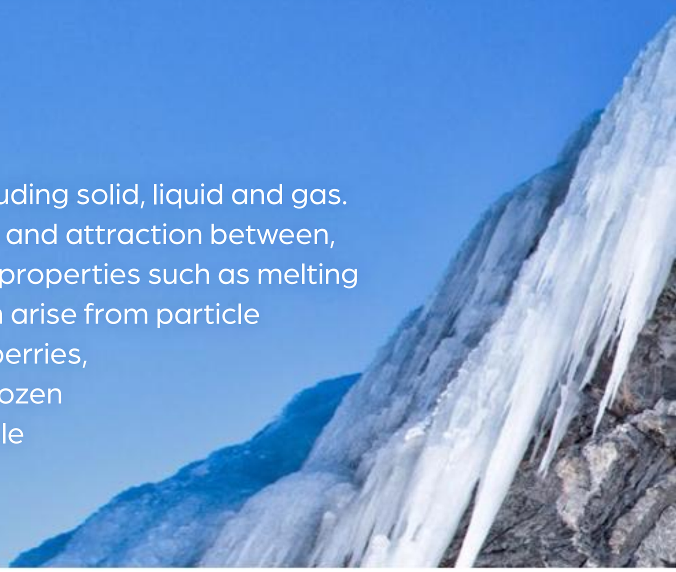
Demonstrate your understanding

3	4	5	
Propose and construct a labelled food chain with the orca as the apex predator.	Compare the adaptations of apex predators in Table 3.3. Select and discuss the adaptation you think is most likely to contribute to the animal's success as a predator.	Predict and discuss how producers in an ecosystem might be affected if an apex predator were removed from the ecosystem.	
Propose and explain evidence that might suggest sharks are not apex predators.	Discuss how theories and models of the idea of apex predators have changed over time.	Research and analyse how First Nations Peoples' perspectives on apex predators have contributed to Western science.	
Explain how ethical considerations could impact the ability of scientists to study physical adaptations of animals.	Discuss how a global economic crisis could affect scientists' ability to progress research about apex predators.	A TikTok video with misinformation about apex predators taking over the world goes viral. Discuss how this could shape worldviews.	
Construct a scatter plot of the average life span of an apex predator and the maximum speed it can travel.	Identify and discuss the relationship between variables displayed in your graph from step 3.	**a** Analyse the links between the qualitative and quantitative information in Table 3.3. **b** Conduct research to find data that supports or disproves your analysis.	Science how-to p. 230
Conduct a search about orcas versus sharks as apex predators. Reference your source.	Construct an evidence-based argument to communicate your position about orcas or sharks as apex predators.	Update your argument from step 4 to address evidence that conflicts with your position.	Science how-to p. 239
Explain two approaches to presenting information about the adaptations of apex predators.	Construct a slide show to present information about the apex predators listed in Table 3.3. Include data acquired from additional research.	Prepare speaker note cards to help you present the slides you prepared in step 4 to a group of your peers.	Science how-to p. 245

Table 3.3: Common apex predators

Apex predator	Life span (years)	Maximum speed (km/h)	Adaptations
Lion	15–30	74	Strong claws and paws
Siberian tiger	15–25	96	Nocturnal hunters and night vision
Saltwater crocodile	60–100+	29	Water-tight flaps over eyes, ears and throat
Orca	30–90	56	Hunt in groups
Bald eagle	20–50	40 (flying)	Sharp, pointed beak
Grey wolf	6–18	60	Long legs
Dingo	4–16	60	Hip and limb flexibility
Polar bear	15–45	40	White fur for low visibility
Wedge-tailed eagle	20–45	35 (flying)	Binocular vision

4.0 Theories of matter



Everything is made of matter, which exists in different states, including solid, liquid and gas. These states are determined by the arrangement and motion of, and attraction between, particles. The particle and kinetic theories of matter explain how properties such as melting and boiling points, density, compressibility, viscosity and diffusion arise from particle behaviour. For example, the melting of chocolate to cover strawberries, the evaporation of sweat during exercise, and the formation of frozen waterfalls all involve changes in states of matter, driven by particle interactions and kinetic energy transfer.

Learning Ladder

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

Steps in progression	Science understanding	Science as a human endeavour	
	Chemical science: Theories of matter	**Nature and development of science**	**Use and influence of science**
5	I can analyse situations that affect the properties and behaviours of substances	I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations
4	I can compare the behaviours of substances in different states	I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues
3	I can use the particle model to explain the properties of substances	I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances
2	I can describe the arrangement and motion of particles in each state	I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society
1	I can identify states of matter	I can recognise scientific problems and solutions	I can identify socio-scientific issues

Figure 4.1: The particle and kinetic theories of matter can be used to describe how this climber is able to summit these ice-covered rocks using limited tools.

Step	Questioning and predicting	Planning and conducting	Processing, modelling and analysing
5	I can evaluate investigation questions and predictions for scientific validity	I can design and conduct reproducible investigations that consider safety, ethical and procedural factors	I can analyse processed data for patterns, trends, relationships and anomalies
4	I can develop a hypothesis that predicts the relationship between investigation variables	I can generate and record data with precision, using digital tools as appropriate	I can identify and discuss trends and/or patterns in a range of dataset representations
3	I can construct questions and predictions to investigate scientific problems	I can distinguish between variables to be changed, measured and controlled in an investigation	I can process data by using mathematical relationships and/or constructing graphs
2	I can make simple predictions based on what I know and observe	I can describe ways to minimise risks for a range of investigations	I can organise and display data using tables, keys and/or models
1	I can recognise questions that can be investigated scientifically	I can identify and select appropriate equipment for scientific investigations	I can identify data from tables and graphs

Steps in progression

Science inquiry

4.1 ▸ The particle theory of matter

Learning intention

At the end of this lesson, I will be able to describe the arrangement and motion of particles, and the attraction between them, in different states of matter.

Key terms

compress: squash something into a smaller shape

gas: the state of matter where the substance expands or contracts to fit the shape and volume of its container

gas pressure: force of gas particles on the walls of their container

liquid: the state of matter where the substance takes the shape of its container but has a fixed volume

matter: any substance that has mass and takes up space

particle: a very small amount of matter

particle theory: a model used to explain the structure and properties of matter

solid: the state of matter where the substance has a fixed shape and volume

volume: the amount of space an object takes up

Investigation 4.1

Compressing liquids and gases, p. 298

Key idea: Matter and energy

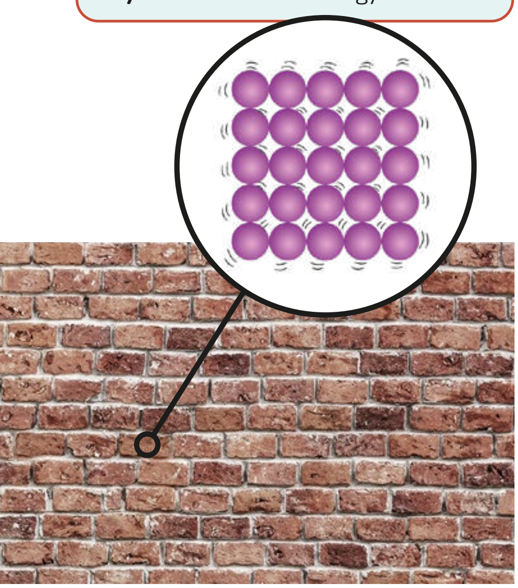
Figure 4.2: Water as a solid and a liquid

Matter is anything that takes up space and has mass. Substances on Earth can exist in three different states of matter: as **solids**, **liquids** or **gases**. The arrangement and movement of **particles** that make up matter can be represented by the particle theory. The **particle theory** says that all matter is made of tiny particles, and that these particles are constantly moving. It can explain why matter behaves in certain ways, and it can predict how it will be affected by changing conditions such as pressure and temperature. We will now look at how this model can be used to describe different states of matter.

The particles in a solid are packed closely together

Solids are materials such as wood, metal or plastic. The particles in solids are packed closely together, like bricks in a wall. However, the particles are not still; they are constantly vibrating.

A solid has a fixed shape and a fixed **volume**. Because the particles in a solid are highly attracted to each other, the solid keeps its shape and does not spread out or flow. A solid cannot be **compressed** easily, because there is not enough space between its particles for them to squeeze closer together. Water exists in its solid state as ice.



◂ **Figure 4.3:** The particles in a solid are packed closely together, like bricks in a wall. They vibrate in their positions.

The particles in a liquid can move past each other

The particles in liquids are not as close together as they are in solids. The particles are still strongly attracted to each other, but they have room to move past each other.

A liquid has a fixed volume but not a fixed shape. A liquid takes on the shape of its container because the attraction between the particles is not strong enough to keep them in fixed positions and shapes. Although liquid particles are more spread out than in solids, a liquid cannot be compressed very much because there is not enough space between its particles for them to squeeze closer together. The liquid state of water is its most common form on Earth.

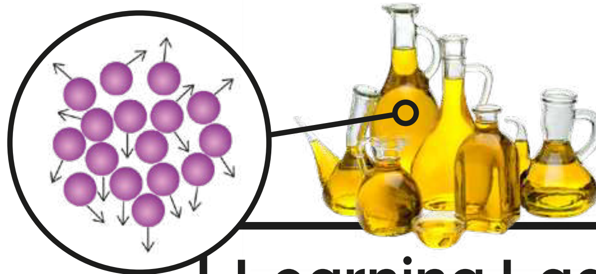


Figure 4.4: The particles in a liquid can move past each other. They take on the shape of their container.

The particles in a gas have large spaces between them

The particles in a gas are weakly attracted to each other, so they can move around more freely than in solids or liquids. The particles have large spaces between them, and they are constantly moving in all directions. Some common gases on Earth are oxygen and carbon dioxide. The air we breathe is a mixture of gases, including oxygen, nitrogen and carbon dioxide.

A gas has neither a fixed shape nor a fixed volume. Gases spread out to fill the container they are in. A gas can be compressed because there is space between the particles. The force of gas particles on the walls of their container is described as **gas pressure**. In a smaller volume, the gas particles have less room to move around, so they will hit the walls of their container more often, increasing the pressure.

Liquid water becomes a gas, known as water vapour, when it is heated. When temperatures rise above 100 °C, the water particles gain enough energy to break free from the liquid state. Water vapour is present in our atmosphere. It can condense to form clouds and eventually fall back to Earth as rain or snow.

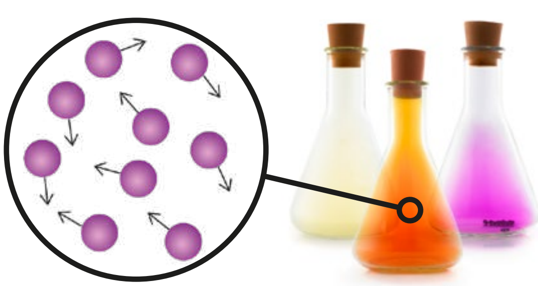


Figure 4.5: The particles in a gas are weakly attracted to each other. They can be squashed into a smaller space.

Learning Ladder

Theories of matter

1. List three solids, three liquids and three gases you have come into contact with today.
2. Describe the properties of gas particles that make gases different from solids and liquids.
3. Explain, with reference to particles, why solids and liquids cannot be compressed easily but gases can.
4. Compare the arrangement, energy level and movement of particles in solids and liquids.

Nature and development of science

1. Identify the problem of trying to fit a large square ice cube into a small round glass.
2. Propose two fields of science that would be interested in studying the cause and effect of hailstorms.

Planning and conducting

p. 226

You observed your teacher heating water (5 mL) in a can over a flame. After 2 minutes, they flipped the can upside down into a container of ice water. The can crushed instantly.

1. Identify a piece of equipment that could be used to flip the can.
2. Describe three ways to minimise risk.
3. You're asked to measure how much the can crushes in mL based on the temperature (°C) of the water in the container (30°C, 60°C, 90°C).
   Identify the independent, dependent and controlled variables.
4. Describe a way you could measure how many mLs the can crushes.
5. Your classmate did not see the demonstration. Construct a step-by-step method they could follow to carry out the investigation, using the variables identified in Question 3.

Key idea: Matter and energy

Construct a descriptive mind map of common examples of solids, liquids and gases that we come across on a daily basis, with reference to particle theory for each example.

Success criteria

- I can recall the three main states of matter.
- I can use particle theory to describe the arrangement of and attraction between particles in states of matter.

4·2 ▸ The kinetic theory of matter

Learning intention

At the end of this lesson, I will be able to describe how heat energy is involved in the particle and kinetic theories of matter.

Key terms

energy: the ability to do work

heat: a type of kinetic energy that is transferred between things

kinetic energy: energy in the form of motion

kinetic theory: a model used to explain the bahaviour of matter in terms of the energy and motion of particles

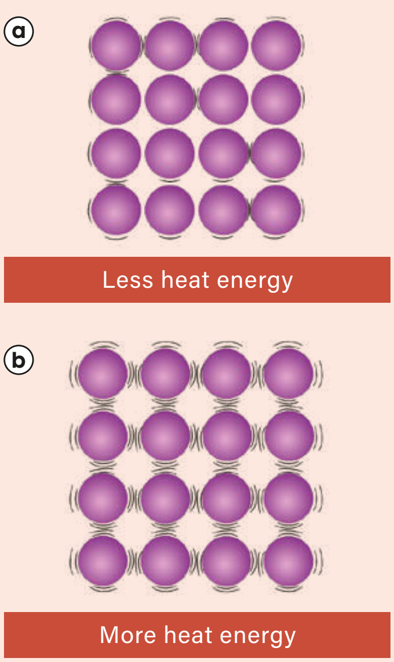
temperature: a measurement of the average kinetic energy of particles in an object

Investigation 4.2

Heating materials, p. 299

Key idea: Matter and energy

Figure 4.6: The more heat you add, the faster the particles in a substance move.



The **kinetic theory** of matter states that all matter is made up of constantly moving particles. A solid object such as a statue does not appear to be moving, but its particles are in constant motion. Their speed of movement depends on the amount of **energy** they have. If the energy of the particles is increased, they will move faster and further away from each other. The particle and kinetic theories go together to explain the behaviour of matter: the arrangement of particles *and* their motion.

Heat is a type of kinetic energy

Energy is needed for matter to do things such as move or change state. **Heat** is a type of **kinetic energy**. The more kinetic energy the particles of a substance have, the faster and further apart those particles will move. Heat can be transferred from one object to another. For example, in Figure 4.7 the heat energy in the electric kettle element is transferred to the water to boil it. The same principle applies in solids. Have you ever rested a metal spoon in a hot drink? At first, the metal handle feels cool, but it soon warms up and can even burn you. This shows that energy is transferred from the bottom of the spoon all the way to the top. The particles at the base of the spoon are heated and begin to move around more. They bounce up against the particles near them, which in turn gain energy, bouncing into the ones near them, and so it continues, all the way up the spoon to the handle. The faster the particles are moving, the hotter the spoon feels.

Temperature is a measure of kinetic energy

The average amount of kinetic energy the particles in a substance have is represented by **temperature**. The higher the temperature of a substance, the faster the particles in that substance are moving. If kinetic energy is added to heat a substance, the temperature will increase. If the motion of particles in a substance is reduced, the temperature will decrease.

There are many ways to cool a hot object. You could put it in the fridge, put it in cold water, or just leave it to cool in the air. Heat energy is transferred from substances with more energy to substances with less energy until the particles in both substances have the same amount of energy. When a substance loses energy in this way, the particles slow down and move closer together, which is reflected by a drop in temperature.

Figure 4.7: When you heat something – for example, water in a ▸ kettle – you are increasing the kinetic energy of the particles.

Changing temperature can change the state of matter

Heating or cooling a substance can cause it to change state. This phenomenon can be explained by the particle and kinetic theories of matter. When particles gain energy, solids change into liquids or liquids into gases. Cooling removes energy, causing gases to become liquids or liquids to become solids. These changes are reversible and demonstrate how temperature, and therefore particle motion and arrangement, affects matter's physical state. Adding or removing heat to and from substances is explored further in Section 4.3.

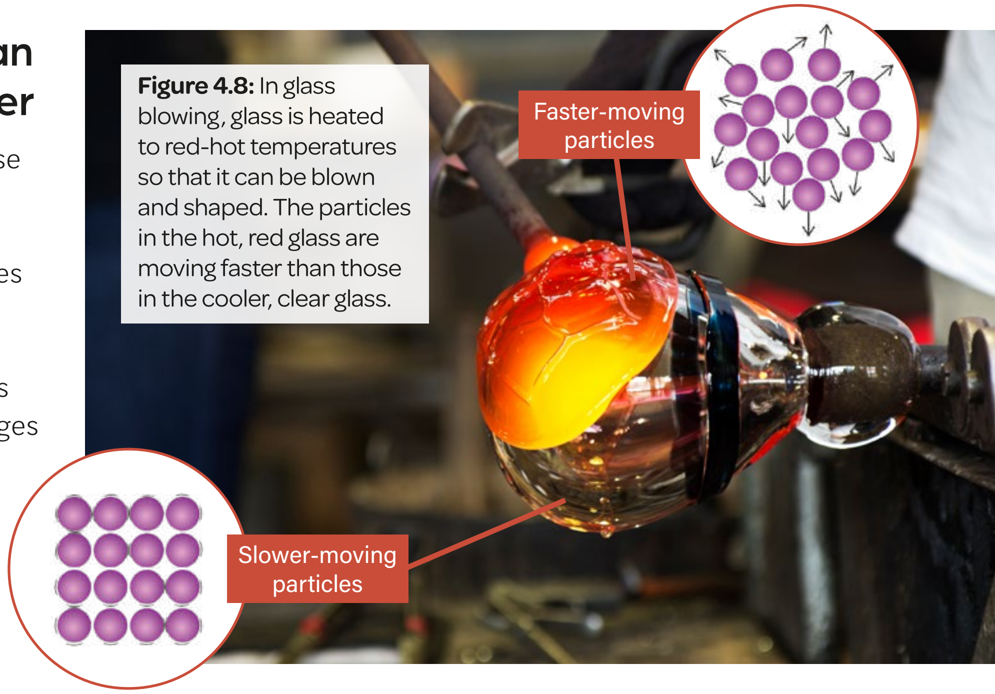


Figure 4.8: In glass blowing, glass is heated to red-hot temperatures so that it can be blown and shaped. The particles in the hot, red glass are moving faster than those in the cooler, clear glass.

Learning Ladder

Theories of matter

1. Heat can travel quickly through ______ substances because the particles are pressed close together, allowing the vibrations to be transferred easily. By contrast, in a ______ or ______, the particles can move freely.
2. Compare the liquid particles in a cup of water heated to 30 °C and particles in a cup of water heated to 45 °C. Propose which cup contains the faster-moving particles. Provide a reason.
3. In terms of the way the particles behave, describe how heating a solid differs from heating a liquid.
4. With reference to the particle model, explain how a large block of ice can have more energy than a small block of wood, even though the temperature of the ice is lower.
5. You remove a steak from the freezer to have for your dinner. Describe how the motion of the particles in the steak would change as it defrosts.

Nature and development of science

1. The Kelvin scale is an alternative temperature scale to Celsius. Zero degrees Kelvin is the point at which particles have slowed down so much, they have actually stopped moving, so there are no negative values. Identify a problem that the Kelvin scale has addressed.
2. Describe why a chemist and a physicist might collaborate to investigate how different substances transfer heat differently.
3. Evidence that mercury expands when it is heated led to the invention of the thermometer. Propose and discuss how this may have led to changes in scientific knowledge about the kinetic theory of matter.
4. Research earlier models of particle and kinetic theories of matter. Summarise how these models changed.
5. Research how First Nations Peoples have traditionally observed and interpreted heat transfer between objects. Propose how their perspectives have contributed to developing modern scientific knowledge.

Processing, modelling and analysing

p. 230

1. Consider Figure 4.6b. Identify what the additional lines in this part of the figure represent.
2. Label Figures 4.6a and 4.6b using a key to model what the circles and lines of the diagrams represent.

Key idea: Matter and energy

Research the glass-blowing process and identify common products that are made using this process. Describe how matter and energy work together to form the products used in society. Propose alternatives to glass blowing that could also produce the products you researched. Discuss their pros and cons.

Success criteria

- I can describe the relationship between the movement of particles and temperature.
- I can describe the kinetic theory of matter with reference to motion and energy.

4.3 ▸ Adding or removing heat

Learning intention

At the end of this lesson, I will be able to describe how heat energy affects the attraction between particles in a substance.

Key terms

pressure: the force applied by gas particles hitting the sides of their container

thermal contraction: the effect of becoming smaller (shrinking) due to the removal of heat

thermal expansion: the effect of becoming bigger (increasing in size) due to the application of heat

Investigation 4.3

Expanding gases, p. 300

Key idea: Matter and energy

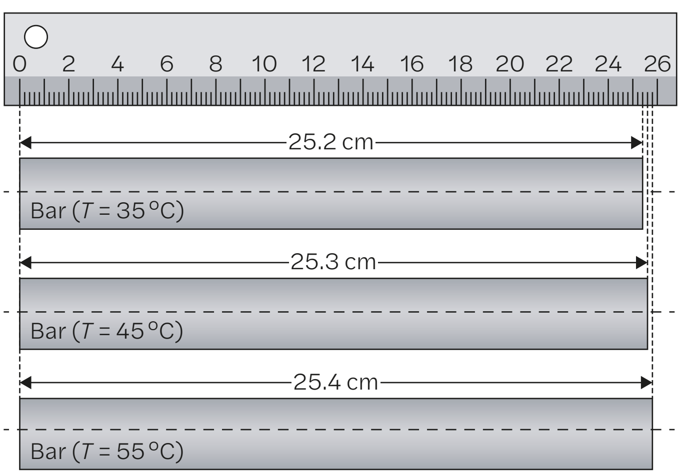
You now know that the the temperature of a substance depends on the speed of movement of its particles. Particles in a hot substance move quickly, while particles in a cold substance move slowly. Some other changes happen when an object is heated (heat is added) or cooled (heat is removed).

Solids expand when they are heated

If you add heat energy to a substance, the particles move faster. Because the particles have more energy and are moving faster, they will move further away from each other, so the substance will expand. This is called **thermal expansion**.

When a solid is heated, it will expand. Different solid substances expand at different speeds and by different amounts. Most solids do not noticeably change their size. Metals are one type of substance that noticeably expands when heated. When metals cool down again, the particles lose energy and move closer together again. This is called **thermal contraction**.

▼ **Figure 4.9:** A metal bar will expand when heated.



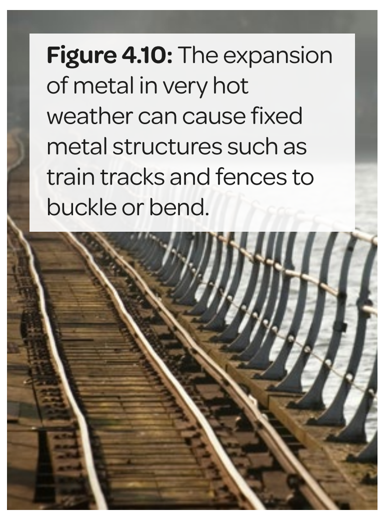
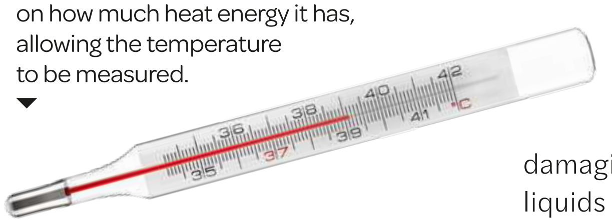


Figure 4.10: The expansion of metal in very hot weather can cause fixed metal structures such as train tracks and fences to buckle or bend.

Figure 4.11: The spaces between the joints in a bridge allow the metal to expand in hot weather without causing the bridge to buckle.

Figure 4.12: The liquid alcohol inside a thermometer takes up different amounts of space depending on how much heat energy it has, allowing the temperature to be measured. ▼



Liquids expand when they are heated

Thermal expansion also happens in liquids. Heating a liquid causes the particles to move more quickly and further away from each other, so liquids will take up a larger volume as they become warm. They will contract as they cool back down again.

Water that is heated without any room to expand can be very damaging. For example, it can cause pipes to burst. The property of liquids expanding when heated can be used safely, such as in alcohol and mercury thermometers. The liquid inside the thermometer expands when the temperature increases (Figure 4.12).

Gases expand or contract with changes in heat

Thermal expansion and contraction also happen in gases. Because the particles in gases are already far apart, the expansion and contraction of gases can be very noticeable.

Although most gases are invisible, you can observe that a warm gas will take up more space than a cold gas by the **pressure** it exerts on its container. You can check this by blowing up a balloon and putting it in a refrigerator. The gases inside the balloon will cool down, reducing the motion of the particles and, therefore, reducing how hard and how often the gas particles hit the sides of the container. This decreases the pressure, which is observed by the balloon contracting and getting smaller, due to its flexible material. Likewise, the air in a hot air balloon expands as it heats up. This causes the balloon to fill, and because the gas becomes more spread out, it becomes lighter than the air surrounding it, which causes the balloon to rise (Figure 4.13).

Figure 4.13: The gas in a hot air balloon will expand when it is heated.

Learning Ladder

Theories of matter

1. Expansion and contraction of ___________ is more noticeable than in liquids or ___________, because their particles are already far apart.
2. Describe what happens to the particles in a substance when:
   - **a** heat energy is added.
   - **b** they lose heat energy.
3. Describe in your own words and with reference to the particle model:
   - **a** the properties of expansion joints in a bridge.
   - **b** how expansion joints prevent a bridge from cracking.

Use and influence of science

1. Using examples provided in this section, identify two socio-scientific issues that could be related to thermal expansion and contraction.
2. Describe an example of a scientific advancement or invention that relies on thermal expansion or thermal contraction to function.
3. Propose and explain the economic impacts of building metal bridges without considering thermal expansion.
4. Discuss how society was impacted when spaces were first inserted between metal joints of large structures.
5. Imagine that you are talking to a friend who says that thermal expansion does not exist because they do not get taller when the weather gets hotter. Outline what you could say to shape their viewpoint about thermal expansion.

Processing, modelling and analysing *p. 230*

1. Figure 4.9 shows a metal bar that is different lengths at different temperatures. Create a table listing the temperatures (°C) that correspond with each length.
2. The length of the bar at 0 °C is 25.0 cm. Add a column to your table that shows how much the length of the bar has increased above 25.0 cm for each temperature.
3. Construct a scatter plot to represent the data in Questions 1 and 2. Include a line of best fit. If needed, see the Science how-to section on page 232.
4. Identify and discuss the relationship between temperature and length shown in your graph.
5. Analyse why there seem to be no anomalies in the experimental data.

Key idea: Matter and energy

Bridges have expansion joints to prevent buckling in hot weather, as shown in Figure 4.11. How else do engineers protect against thermal expansion when building structures? Research and discuss two other strategies that can be used. In your response, refer to the particles of the materials.

Success criteria

- I can predict the effect of adding or removing heat on solids, liquids and gases.
- I can explain how substances expand or contract, with reference to the particle and kinetic theories of matter.

4·4 ▸ Changing states

Learning intention

At the end of this lesson, I will be able to describe what happens when matter changes states, with reference to the particle and kinetic theories of matter.

Key terms

boiling point: the temperature at which a liquid vigorously changes to a gas

condense: the process of changing state from gas to liquid

deposition: the process of changing state from gas to solid without going through the liquid state

evaporation: the process of changing from liquid to gas

freeze: change state from liquid to solid

melt: change state from solid to liquid

melting point: the temperature at which something changes from a solid to a liquid

sublimation: the process of changing state from solid to gas without going through the liquid state

Investigation 4.4A

Changing states of water, p. 301

Investigation 4.4B

Exploring melting points, p. 303

Key idea: Matter and energy

Figure 4.14: ▸ When particles in a solid such as wax speed up, the solid can melt to form a liquid.

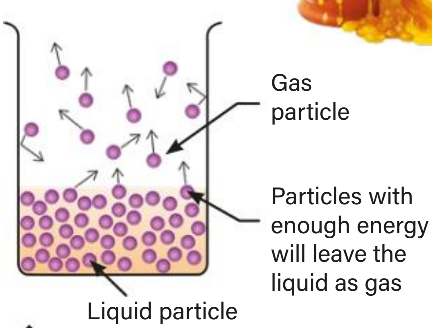
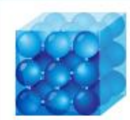
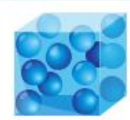


Figure 4.15: Particles near the surface of a liquid become a gas during evaporation.

Water is the only substance on Earth that exists naturally in states: as a solid, a liquid and a gas. Solid water is ice. If you heat it, the ice melts into liquid water. If it continues to gain energy, it evaporates or boils and becomes water vapour.

Recall that there is empty space between particles, which are constantly moving. The particle model and your understanding of how heat affects particles can be used to explain changes in state (Table 4.1).

Table 4.1: The arrangement of particles in the three states of matter

State of matter	Particle arrangement	Diagram	Forces
Solid	Closely packed; vibrate in place		Strong forces hold the particles together
Liquid	Loosely packed; can slide over one another		Moderate forces hold the particles near each other
Gas	Moving freely around the available volume; always moving and colliding		Weak forces between the particles allow them to move around

Solids can melt and liquids can evaporate

When heat energy is added to matter, the energy is transferred to its particles. This causes the particles to vibrate and move more, which can result in the substance changing states. As the particles move more, they can overcome the forces holding them together. We can see this when we add energy to ice (solid water). The ice **melts** and becomes liquid at 0 °C. The **melting point** is the temperature when a solid changes to a liquid. This is different for every substance.

If we continue to add energy, the liquid water can evaporate into a gas. **Evaporation** is the change of a liquid to a gas. Evaporation can happen at any temperature. In any liquid, some of the particles on the surface will have enough energy to break away from the others, becoming a gas. Evaporation is the reason that a puddle will eventually shrink and disappear, even during cool weather.

Boiling is when a liquid is heated to a specific temperature that causes evaporation to happen vigorously. This temperature is called the **boiling point**. This point is different for every substance. When they have enough heat energy, the particles in the liquid move so quickly that they become a gas inside the liquid. This gas can be seen as bubbles that rise through the liquid and escape.

Liquids can freeze and gases can condense

When matter loses heat energy, the particles lose energy and start to move less. The particles also become closer together because they no longer have enough energy to overcome the forces of attraction between them.

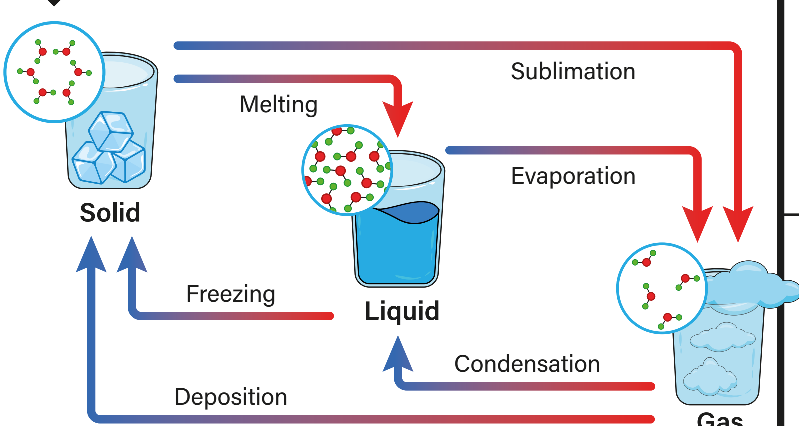
We can see this process with water. When we place a cold glass of drink on a table, gaseous water vapour from the surrounding air **condenses** on the side of the glass as liquid. If we put that same glass into the freezer, below 0 °C, then the water **freezes** into ice.

Solids can become gases and gases can become solids

At room temperature, we exhale carbon dioxide gas into the air around us. At very low temperatures, carbon dioxide becomes a solid called dry ice. To stay solid, dry ice needs to be stored at −79 °C. When the temperature rises above −79 °C, the solid turns directly into carbon dioxide gas without going through the liquid state. It produces a white 'fog'. This process of changing directly from a solid to a gas is called **sublimation**. The reverse of this process, changing directly into solid carbon dioxide from the gas, is called **deposition.** Another example of deposition is when water vapour in the air forms solid frost on a cold morning.

Figure 4.16: Dry ice (solid) sublimes at room temperature, turning immediately into a gas.

Figure 4.17: There are many processes that can take place between solids, liquids and gases that lead to a change in the state of matter.



Learning Ladder

Theories of matter

1. Using Figure 4.17, identify the process occurring for the following state changes.
   - **a** A kettle converts liquid water into steam.
   - **b** Water vapour in the clouds forms hail.
   - **c** You use a fondue pot to dip strawberries into chocolate.
2. Describe how the particles of a solid substance would change if it were heated past its boiling point.
3. Explain scientifically how water can change from a solid to a gas and then back to a solid.
4. Compare the properties of solids, liquids and gases with reference to particle theory.
5. Evaluate the following statement: 'Evaporating and boiling is the same thing because a liquid is changing to a gas'.

Use and influence of science

1. Propose an economic issue that is related to accelerated evaporation in warm climates.
2. Dry ice (Figure 4.16) can be used to create special effects in theatre productions. Describe how this might have improved the productions.

Questioning and predicting p. 222

1. Propose whether the following question can be investigated scientifically and provide a reason. *What is the boiling point of water?*
2. Propose whether salt water has a lower or higher boiling temperature than pure water. Provide a reason for your prediction.
3. Construct a scientific question that can investigate the melting points of different types of cheese.
4. Research the cheeses you identified in Question 3. Develop a supported hypothesis that predicts the relationship between melting points and types of cheese.

Key idea: Matter and energy

Plasma is sometimes called the fourth state of matter. Use the internet to research plasma and discuss how it differs from the other three states of matter, with reference to the particle and kinetic theories of matter.

Success criteria

- I can describe the physical changes observed when substances change between states.
- I can explain state changes with reference to the particle and kinetic theories of matter.

4.5 ▸ Properties and behaviours of substances

Figure 4.18: How is a heavy warship able to float on water?

Learning intention

At the end of this lesson, I will be able to explain the properties and behaviours of substances in terms of the particle and kinetic theories of matter.

Key terms

concentration: the number of particles in a given space; particles crowded in one place is high concentration

density: how heavy something is for its size; mass divided by volume

diffusion: the movement of particles from areas with more particles to areas with fewer particles

mass: the amount of matter that an object contains

viscosity: how easily a liquid can flow

Investigation 4.5

Exploring density, p. 304

Key idea: Matter and energy

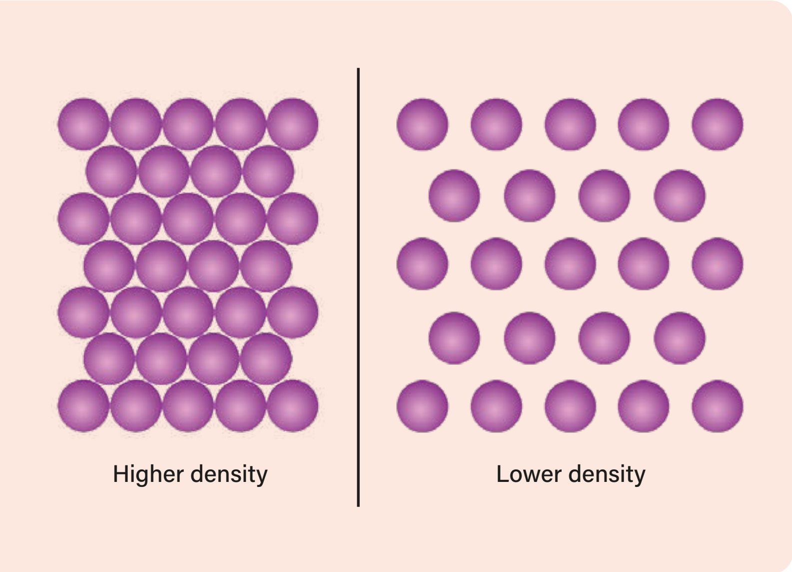
Why do some objects float while others sink? It's not just about mass. There is another important factor. Massive icebergs float, while small coins sink, due to a property of matter called density. Substances also have other unique behaviours. 'Viscosity' describes how easily a liquid flows, while diffusion is how particles spread out. These properties and behaviours help us to understand the world around us, from floating ships to the way smells travel through the air.

Density is how heavy an object is for its size

You can calculate the density of an object by dividing its **mass** by its volume. In other words, **density** is a measure of how heavy an object is compared to its size.

Solids usually have higher densities than gases and liquids because their particles can pack more closely together. A coin may be lighter than a log, but a coin-sized piece of the log would be lighter than the coin because metals are denser than wood. So, when comparing two objects of the same size, the heavier one has a greater density.

Figure 4.19: The particles on the left are more closely packed than the particles on the right. A substance with particles that are closely packed has a high density.



Density can be explained by particle theory

In terms of particle theory, density is related to two things: the amount of space between particles and the mass of the particles (see Figure 4.19):

- The more tightly packed its particles are, the denser an object is.
- The heavier its particles are, the denser the object is.

Imagine a bike with an aluminium frame and an identical bike made of steel (iron metal). Although the bikes are the same size, the steel bike is heavier because iron atoms have more mass than aluminium atoms.

Liquids and gases with lower density float on those with higher density

Liquids and gases with a lower density float on top of substances with a higher density (see Figure 4.20).

Have you ever heard that 'hot air rises'? This is because hot air is less dense than cool air. The spaces between the particles in the hot air are larger than the spaces between the particles in the cool air. This is what keeps a hot air balloon in the sky.

The warship in Figure 4.18 floats on water, so it must have a lower density than water. Even though the ship is made of metal, most of the inside of a warship is air. The air takes up a lot of volume but has very little mass. So, overall, the ship and the air inside it has a lower density than water.

Figure 4.20: Liquids of different densities in a container will arrange so that the liquid with the highest density is at the bottom and the liquid with the lowest density is at the top.

The different states of water have different densities

Water is a very unusual substance because its particles move further apart when it freezes. This means that ice is less dense than water and can float on water (see Figures 4.21 and 4.22). Water is in its most compact arrangement and at its most dense as a liquid at 4 °C. At lower temperatures, the water particles spread out and the water becomes less dense.

Figure 4.21: Ice is less dense than water, which is why icebergs float.

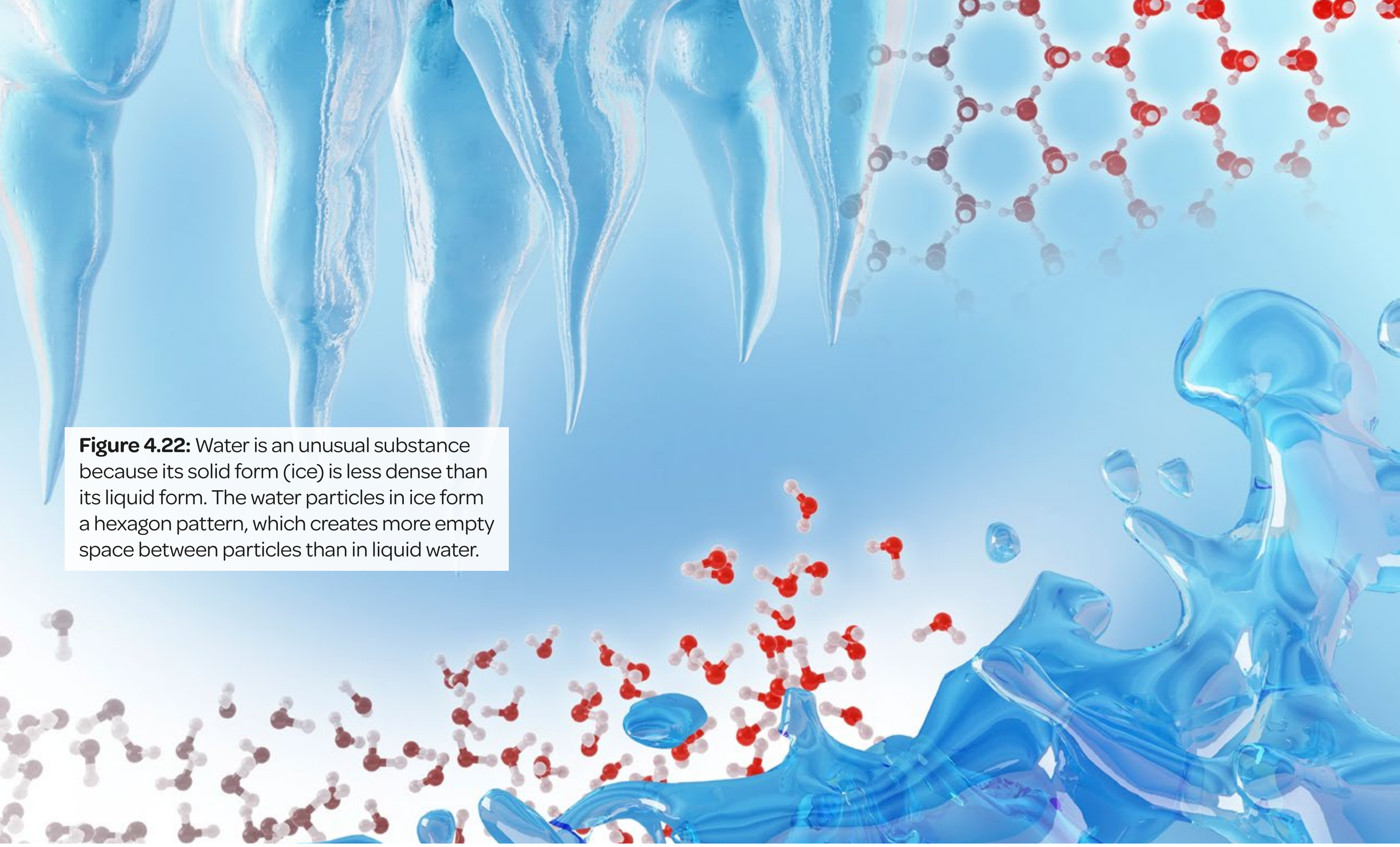


Figure 4.22: Water is an unusual substance because its solid form (ice) is less dense than its liquid form. The water particles in ice form a hexagon pattern, which creates more empty space between particles than in liquid water.

As water at the surface reaches 0 °C, it freezes. The water below the ice is at 4 °C and sinks because it has a higher density. This creates a pocket of air between the two layers. The air acts as an insulator, which is crucial for the survival of aquatic life during winter months.

Water vapour is the gaseous state of water, formed when liquid water evaporates into the atmosphere. Water vapour is much less dense than liquid water and ice. Water vapour is also less dense than air, which is why it rises in the atmosphere. This property is very important in the water cycle, as water vapour condenses to form clouds and eventually falls back to Earth as rain or snow.

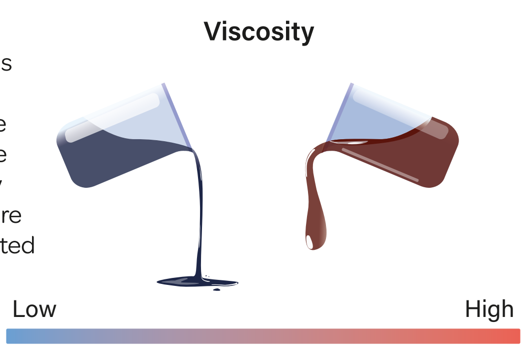
Viscosity is how easily a substance can flow

Have you ever tried pouring honey on your toast and noticed how slowly it moves? Now think about how quickly water pours from a bottle. This difference is due to **viscosity**, a property that describes how easily a liquid flows. Liquids with high viscosity, like honey and syrup, flow slowly, while low-viscosity liquids, like water and juice, move quickly and easily.

Recall that kinetic theories of matter state that all substances are made of tiny moving particles. In thick liquids like honey, the particles are packed closely together and are strongly attracted to each other. This makes it harder for them to move past one another, so the liquid flows slowly. In contrast, water has particles that are less attracted to each other, allowing them to move more freely and to slide past each other easily, resulting in a faster flow.

You can see viscosity in action every day! Try tilting a bottle of shampoo and a bottle of cooking oil at the same time. Which one moves faster? You can also experiment by putting a spoon in honey and then in milk – notice how different they feel when you try to stir.

Figure 4.23: A highly viscous liquid will flow slowly because its particles are packed closely together and are strongly attracted to each other.



Diffusion is how particles spread out

Diffusion is what allows you to walk past a bakery and smell the freshly baked bread from outside the shop. It is the process where particles spread from areas of high **concentration** (like near the bread) to areas of low concentration (outside the shop). This is why smells, gases and liquids can mix on their own over time.

Recall that particles in all substances have kinetic energy, which is observed as constant motion. When particles are crowded together in one place (concentrated) but are free to move past each other as in gases and liquids, they naturally spread out in the space around them to create a balance of particles. This is why food colouring slowly spreads in a glass of water without stirring. The food colouring particles are concentrated when they are dropped into the water, but over time they spread themselves evenly into areas without food colouring (low concentration), until there is a balanced amount of food colouring throughout the water.

Figure 4.24: ▶ Due to diffusion, drops of food colouring will eventually spread evenly throughout a glass of water, even without stirring.

Learning Ladder

Theories of matter

1. Identify which substance has a greater viscosity: tomato sauce or milk. Provide a reason.
2. Describe the property of water that allows a drop of food colouring to spread throughout it.
3. Explain why two objects can have different masses, even though they are the same size.

Use and influence of science

1. Identify a socio-scientific issue related to ice being less dense than water in relation to ships in arctic environments.
2. Propose how scientific knowledge can address the issue identified in Question 1.
3. Biofuels can benefit the environment, but they are often more viscous than standard fuel. Propose and explain an economic impact of using biofuel, especially in cold environments.

Planning and conducting *p. 226*

Refer to Investigation 4.5, 'Exploring density' (page 304). Read the aim, materials and method.

1. Identify the piece of scientific equipment required to measure the volume of water.
2. Identify any hazards associated with the piece of equipment you identified in Question 1. Describe how you would minimise the risk.
3. For this investigation, identify:
   a the independent variable.
   b the dependent variable.
   c two controlled variables.
4. Propose how you might generate digital data in this investigation. Identify the equipment that would be required and how it would be used to collect digital data.
5. Design an investigation that explores how temperature affects the viscosity of honey. Propose an aim, identify the variables and outline the method steps. Be sure to include safety and ethical considerations.

Key idea: Matter and energy

A type of star known as a neutron star contains some of the densest material in the universe. Research the materials found inside a neutron star and suggest why they might be so dense.

Success criteria

- I can describe density, diffusion and viscosity.
- I can use particle theory to explain examples of density, diffusion and viscosity in everyday life.

4.6 ▸ Key idea: Matter and energy – water as a solvent

Learning intention

At the end of this lesson, I will be able to describe the importance of water as a solvent in daily life, industry and the environment, in terms of matter and energy.

Key terms

aqueous solution: a solute dissolved in water

dissolve: particles separating and spreading out, so that they seem to disappear, when added to another substance

mixture: two or more substances combined that can be physically separated

solubility: the amount of solute that will dissolve in a solvent

solute: a substance that is dissolved by a solvent

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

solvent: a substance that a solute dissolves in

universal solvent: a solvent that dissolves most substances

Investigation 4.6A

Water as a solvent, p. 306

Investigation 4.6B

Solubility and temperature, p. 307

Key idea: Matter and energy

Water is a special type of matter that is vital for life on Earth: without water we could not survive. Our bodies need water, and so do the plants that we eat. We also need water for daily activities such as cooking and washing. We use water to extract minerals from underground and to make medicines. Water is known as the **universal solvent** because it **dissolves** more substances than any other liquid.

Water is a solvent in daily life

Water can dissolve many other substances: solids, liquids and gases. When these substances dissolve, they are called **solutes**. Any **mixture** that has water as a **solvent** is called an **aqueous solution**.

Water acts as a solvent in daily life in many ways:

- **Human survival:** Water is an essential solvent for humans. Blood is mostly water, and it carries dissolved nutrients and oxygen around our bodies.
- **Preparing meals:** Water dissolves spices, flavours and other ingredients as food cooks.
- **Washing away dirt:** Water acts as a solvent for soaps and detergents when cleaning dishes, clothes and ourselves.

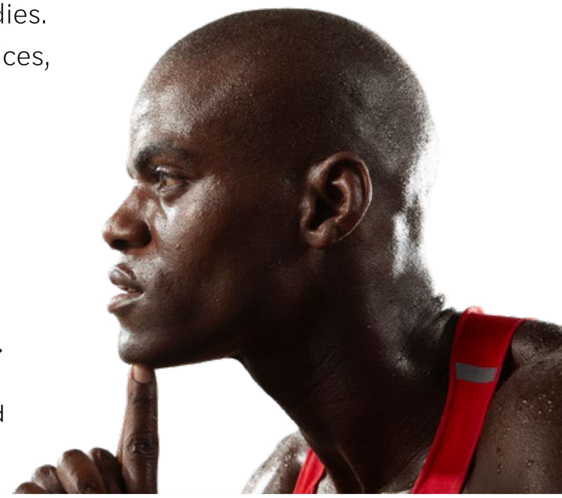


Figure 4.25: Water is a solvent for important minerals in our bodies. When we exercise intensely, we lose water and minerals dissolved in our sweat.

Figure 4.26: Water is essential for daily living.

Water is used as a solvent in industry

Industries such as mining use water as a solvent to extract different types of matter from the earth such as elements and mineral compounds. The element uranium is found in rocks deep underground. Uranium is used as a fuel in the reactors of nuclear power plants and to power nuclear submarines.

In Australia, some uranium mines use water as a solvent to remove the uranium from the rocks. Instead of digging up the rocks to remove the uranium, acids are dissolved into water that is then pumped into the rocks containing the uranium. The acidic **solution** dissolves the uranium, and the acidic water is then pumped back to the surface where it is processed to access the uranium.

Figure 4.27: The Mary Kathleen uranium mine operated in Queensland from the 1950s to the 1980s.

Water is used as a solvent in the environment

Many essential elements of matter, such as iron, zinc and calcium, are needed by plants and animals. They are found as minerals in rocks and soil. Water can dissolve many of these minerals, so plants can absorb them from groundwater. Animals eat the plants, receive these essential nutrients and are able to survive.

The water in rivers, lakes and oceans contains dissolved oxygen that is vital to fish and other animals. Similarly, water contains dissolved carbon dioxide, which marine plants need in order to photosynthesise.

Figure 4.28: Water is essential to the survival of plants and animals.

Energy affects how much matter dissolves in water

The properties of water change as the temperature changes. As heat energy is added, water particles absorb more energy and move more. This means they become better at dissolving matter: the warmer the water, the more solute it can dissolve and the greater the **solubility** of the solute.

Learning Ladder

Theories of matter

1. Recall why water is called the universal solvent.
2. Describe how adding heat energy affects the solubility of a solute.
3. Explain how an increase in temperature affects solubility, with reference to the particle and kinetic theories of matter.
4. Describe how water can be used as a solvent in mining.

Nature and development of science

1. Propose a problem that could arise if oxygen could not be dissolved in water.
2. Describe a use for water in industry that would require nuclear and environmental chemists to collaborate.

Questioning and predicting p. 222

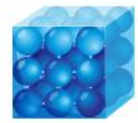
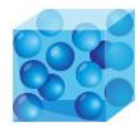
1. Identify which of the following questions can be investigated scientifically.
   A Why is water the universal solvent?
   B How much salt can dissolve in 100 mL of water?
   C How do you make an acidic solution?
2. Make a prediction for the question you selected in Question 1.
3. Construct a scientific question to investigate the solubility of sugar in water at different temperatures.
4. For your scientific question from Question 3:
   a Identify the independent and dependent variables.
   b Develop a hypothesis using an 'If ..., then ...' statement.
4. Evaluate the validity of your prediction from Question 4 with reference to particle and kinetic theories of matter.

Success criteria

- I can describe how water is used as a solvent in daily life, industry and the environment.
- I can explain how matter and energy are involved in the concept of water as the universal solvent.

Summary

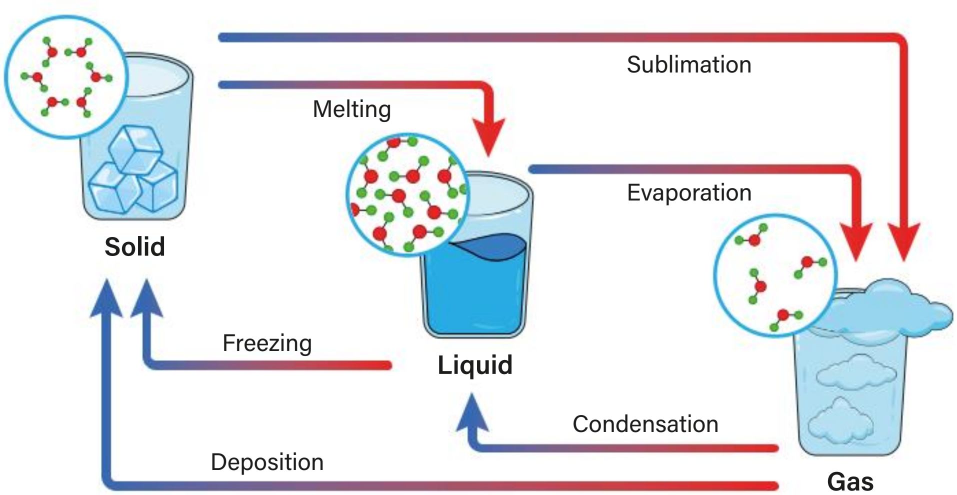
- Matter is anything that takes up space and has mass. It is made up of tiny particles.
- Particle theory describes the arrangement of particles in the three states of matter.

State of matter	Particle arrangement and behaviour	Diagram	Forces
Solid	Closely packed; vibrate in place Cannot be easily compressed		Strong forces hold the particles together
Liquid	Loosely packed; can slide over one another		Moderate forces hold the particles near each other
Gas	Moving freely around the available volume; always moving and colliding Can be easily compressed		Weak forces between the particles allow them to move around

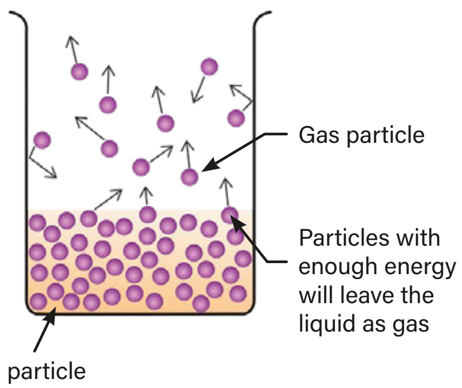
- Kinetic theory of matter describes the movement of particles in matter.
- The particle and kinetic theories of matter can be used to explain the properties and behaviour of substances.

- Solids, liquids and gases expand when they are heated and contract when they are cooled.

- Matter changes state as heat energy is added or removed. Processes that take place when matter changes state are: melting, freezing, sublimation, evaporation, condensation and deposition.

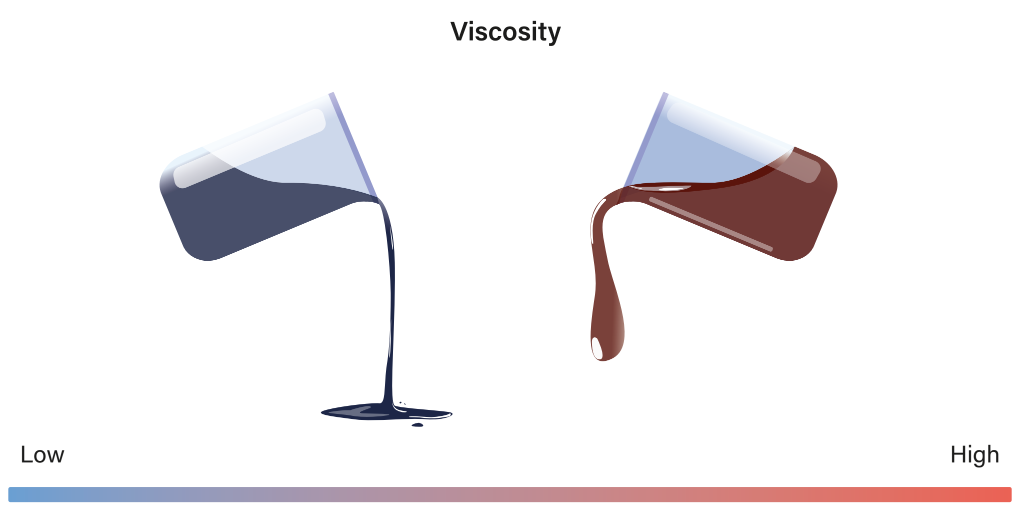


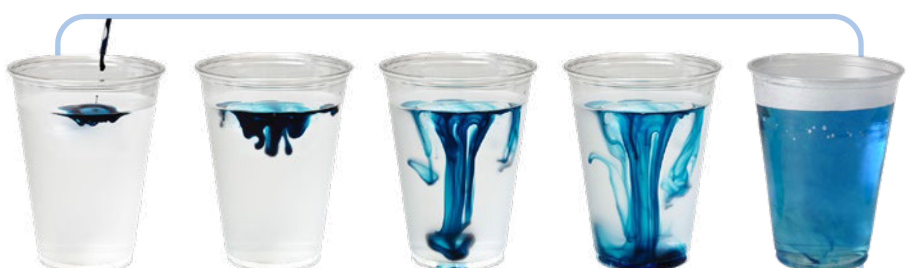
- Melting point is the temperature at which particles change from a solid to a liquid.
- Boiling point is the temperature at which particles throughout a substance have enough energy to change from a liquid to a gas. This is similar to evaporation, but evaporation can take place at any temperature.



- Density is how heavy a substance is compared to its size. It can be explained by the particle theory of matter.
- Liquids that are mixed together can separate into layers based on their density.

- Viscosity is how easily a substance can flow. Particles that are more attracted to each other will be thicker and flow more slowly, while particles that are less attracted to each other will flow faster.





- Diffusion is how particles spread through a substance, due to their constant motion and tendency to move to spaces where there is more room, until a balance is established.

Key idea: Matter and energy

- Water is known as the universal solvent because it can dissolve more substances of matter than any other liquid.
- Water is necessary in everyday life, industry and the environment.
- Energy affects how much matter can be dissolved in a given amount of water.

Masterclass

Steps in progression

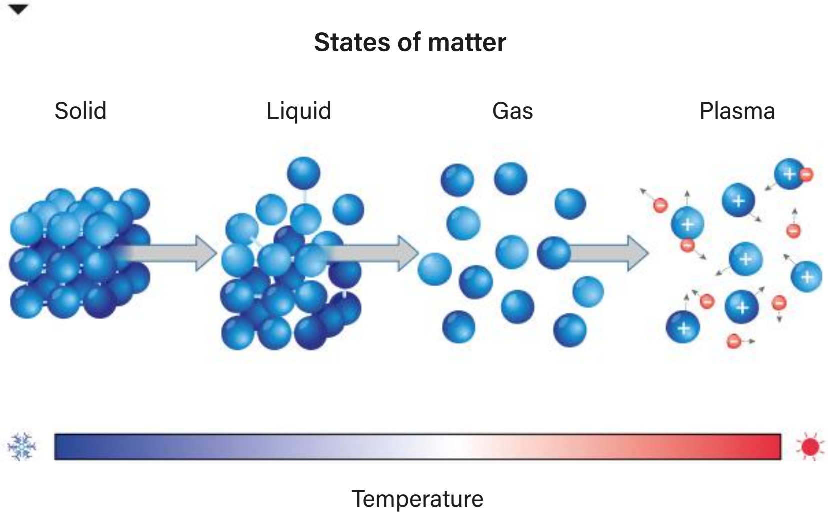
		1	2
Science understanding	**Theories of matter**	List the four states of matter.	Describe how the arrangement of particles progresses from solid matter to plasma.
Science as a human endeavour	**Nature and development of science**	Propose how making plasma on Earth could present a problem.	Describe a situation involving plasma that might require collaboration across multiple disciplines of science.
Science as a human endeavour	**Use and influence of science**	Neon lights require a lot of energy. Identify a related socio-scientific issue.	Propose how knowing that lightning is a form of plasma might affect society.
Science inquiry	**Questioning and predicting**	Fix this question so it can be investigated: *Why does plasma conduct electricity?*	Predict whether plasma televisions contain actual matter in plasma form.
Science inquiry	**Planning and conducting**	Identify three pieces of equipment that would be required to test how heat affects states of matter.	Describe ways to minimise risk associated with using heat in the laboratory.
Science inquiry	**Processing, modelling and analysing**	Recall what percentage of matter in the universe is in the form of plasma.	Construct a table to collect secondary data about how temperature affects particle arrangement in the four states of matter.

Plasma: a fourth state of matter

Plasma is a state of matter that is not commonly discussed in Year 7 Science classes. So, you might be surprised to know that most of the matter in the universe is made of plasma. In fact, about 99 per cent of all known matter is plasma!

Plasma is a special kind of gas whose particles have so much energy the atoms lose some of their electrons. This creates a mix of free-moving electrons and positively charged particles. The combination makes plasma behave differently from regular gases. For example, plasma can conduct electricity and react to magnetic fields.

Figure 4.29: Plasma is similar to gas but has freed electrons from atoms due to high temperatures, making it electrically and magnetically charged.



Demonstrate your understanding

3	4	5	
Explain how temperature is related to the four states of matter, using the kinetic theory of matter in your response.	Compare the properties of gas and plasma in relation to their particle make-up.	Analyse the similarities and differences between stars and lightning, with reference to the properties of substances.	
Explain how evidence of plasma may have led to the acceptance that there is a fourth state of matter.	Figure 4.29 is a model of how temperature is related to states of matter. Predict how this model has changed over time.	Some cultures believe stars and lightning to be something other than plasma. Investigate how varying perspectives can be respected equally.	
Explain how using plasma science to predict where lightning will strike could impact social and/or environmental issues.	Propose and discuss the impacts of plasma televisions on socio-scientific issues.	Analyse how space exploration can be viewed by people, considering the study of stars has helped us understand plasma on Earth.	
Construct a scientific question that could investigate the relationship between temperature and states of matter.	Develop a hypothesis to predict the relationship between variables for the question you constructed in step 3.	Justify your hypothesis in step 4 using the particle and kinetic theories of matter, with reference to plasma as a fourth state of matter.	Science how-to p. 222
Identify the independent variable, dependent variable and controlled variables for the question you posed in the above question set.	Research ways that scientists have tested the properties of plasma in a laboratory. Discuss the techniques that were used to generate data.	Design a step-by-step investigation to test your hypothesis from the above question set.	Science how-to p. 226
Use secondary sources to sketch a scatter plot of the relationship between temperature and the strength of attraction between particles.	Identify and discuss the trend in the graph from step 3.	Analyse the relationship between particle attraction and the four states of matter. Propose questions you still have about the patterns in the data.	Science how-to p. 230

You can find plasma in some amazing places, like flames, stars and lightning. It takes a lot of energy to create plasma. For example, lightning forms when electrical charges in the air build up enough energy to change the gas into plasma. The Sun and other stars are made of super-hot plasma, where atoms are constantly colliding and releasing huge amounts of energy.

Figure 4.30: Lightning seen in thunderstorms is a form of plasma.

Plasma is also used in everyday technology! Fluorescent lights and neon signs work because of plasma. Inside the tube of a fluorescent light, an electric current passes through a gas to create plasma. This plasma gives off ultraviolet light, which then makes a special coating inside the tube glow, producing the light we see.

Figure 4.31: ▶ Fluorescent lights use electricity to convert gas to plasma.

5.0 Mixtures

Is it important to know what everything is made of? Have you ever noticed how, by combining various ingredients in the kitchen, you can create something new? Take making pasta, for instance. When you cook pasta, you are working with mixtures — whether it is the water you boil the pasta in or the sauce you thicken by evaporating excess moisture. Even the soft drink you enjoy with your meal is a mixture, a solution where one substance dissolves into another.

But what makes mixtures unique? Unlike pure substances, mixtures can be separated back into their individual components. There are various techniques to do this, and knowing which one to use can make all the difference. From cleaning up oil spills to separating the components in blood, separation methods are vital tools in science and in everyday life. Understanding how and why mixtures behave the way they do helps us to make sense of the world around us.

Learning Ladder

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

Steps in progression	Science understanding: Chemical science: Mixtures	Science as a human endeavour: Nature and development of science	Science as a human endeavour: Use and influence of science
5	I can discuss examples of separation techniques used in society	I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations
4	I can select and apply techniques to separate substances in mixtures	I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues
3	I can explain how mixtures can be separated based on the properties of their components	I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances
2	I can describe the composition of different types of mixtures	I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society
1	I can distinguish between pure substances and mixtures	I can recognise scientific problems and solutions	I can identify socio-scientific issues

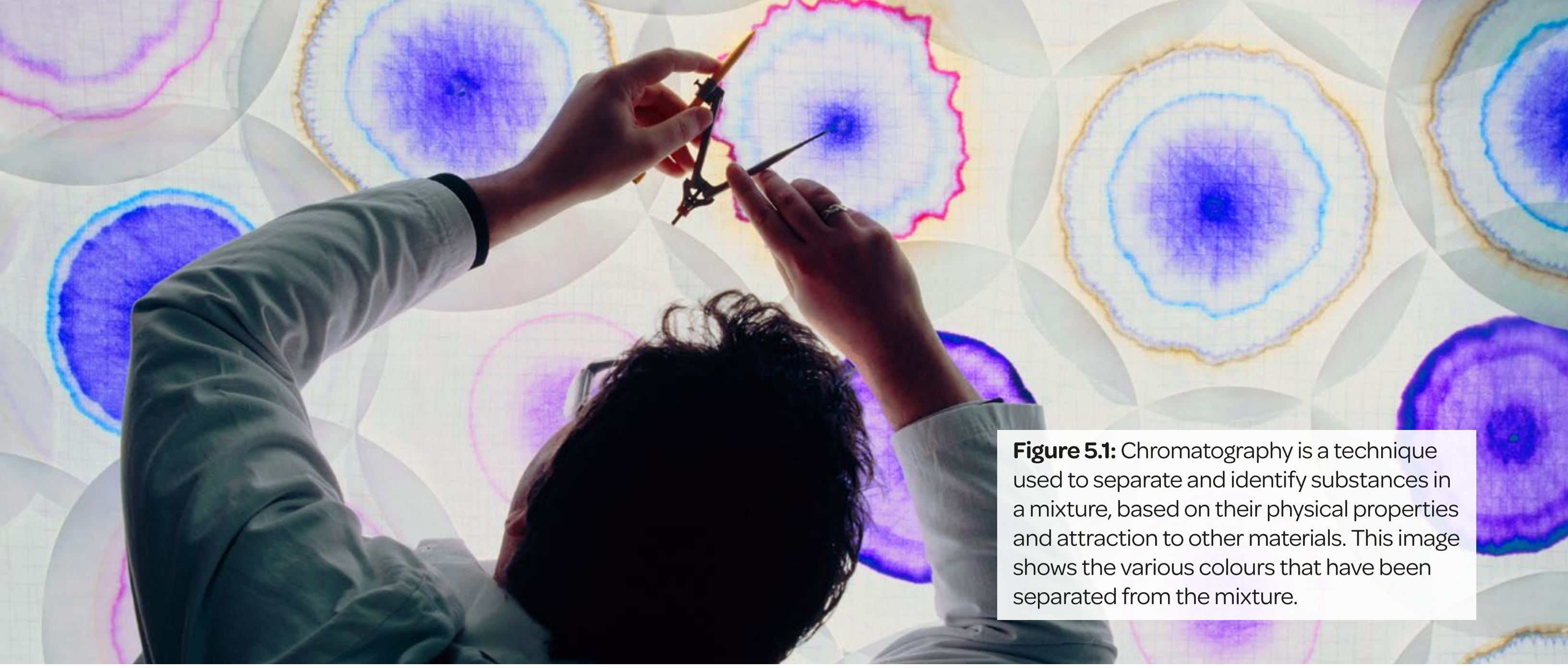


Figure 5.1: Chromatography is a technique used to separate and identify substances in a mixture, based on their physical properties and attraction to other materials. This image shows the various colours that have been separated from the mixture.

Planning and conducting	Processing, modelling and analysing	Evaluating	Steps in progression
I can design and conduct reproducible investigations that consider safety, ethical and procedural factors	I can analyse processed data for patterns, trends, relationships and anomalies	I can evaluate conclusions and claims with reference to conflicting evidence and unanswered questions	5
I can generate and record data with precision, using digital tools as appropriate	I can identify and discuss trends and/or patterns in a range of dataset representations	I can create evidence-based arguments to justify conclusions or evaluate claims	4
I can distinguish between variables to be changed, measured and controlled in an investigation	I can process data by using mathematical relationships and/or constructing graphs	I can use science-based explanations to support investigation findings	3
I can describe ways to minimise risks for a range of investigations	I can organise and display data using tables, keys and/or models	I can describe different types of errors in an investigation method	2
I can identify and select appropriate equipment for scientific investigations	I can identify data from tables and graphs	I can identify errors and assumptions in an investigation	1

Science inquiry

5·1 ▸ Pure and impure substances

Figure 5.2: Gold is one of the few substances that exists in its elemental form in nature.

Learning intention

At the end of this lesson, I will be able to distinguish between elements, mixtures and compounds and classify them based on their properties by using particle theory (see Section 4.1 in Chapter 4) and composition.

Key terms

chemical bond: a force that holds atoms together

colloid: a mixture made of tiny insoluble particles that remain dispersed evenly in a liquid

compound: a substance containing atoms of two or more elements chemically bonded together in a fixed ratio

element: a substance made of only one type of atom

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

homogeneous: a mixture in which one substance (the solute) is uniformly dissolved in another, resulting in a uniform composition

lattice: a three-dimensional shape made of a repeating pattern of atoms

mixture: a combination of two or more elements and/or compounds that can be separated

suspension: a mixture made of large insoluble particles that settle to the bottom of the liquid

Investigation 5.1

The Tyndall effect, p. 309

Key idea: Scale and measurement

Substances can be elements, compounds or mixtures, which are all made up of atoms. Elements are made up of one type of atom. Elements bond together to form compounds made up of more than one type of atom. A mixture can contain many types of substances or particles, but the parts of the mixture are not bonded together and can be separated.

Matter can be divided into pure substances and impure substances

Matter can be divided into pure substances and impure substances (see Figure 5.3). A pure substance is composed of only one type of particle. Pure substances include elements (made up of one type of atom) and compounds. Compounds are made of two or more types of elements chemically joined together into particles that cannot be physically separated.

An impure substance is made up of two or more substances that can be separated. Impure substances include mixtures, which can be physically separated into their different components. Air (a mixture of different gases), milk (made of water, fat, protein and other substances) and salt water (salt mixed with water) are all examples of mixtures.

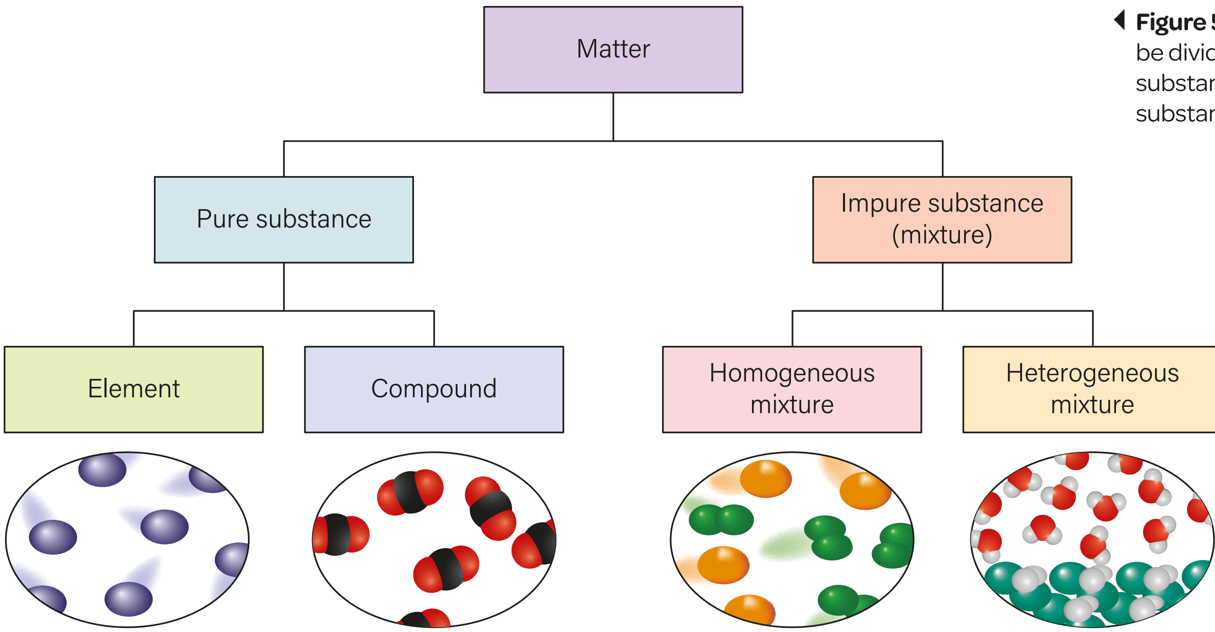


Figure 5.3: Matter can be divided into pure substances and impure substances (mixtures).

An element contains only one type of atom

An **element** is a pure substance that is made up of only one type of atom. Gold is an element because it consists only of gold atoms. Likewise, aluminium is made only of aluminium atoms, and hydrogen gas is made of only hydrogen atoms. Elements cannot be broken down further by ordinary chemical means.

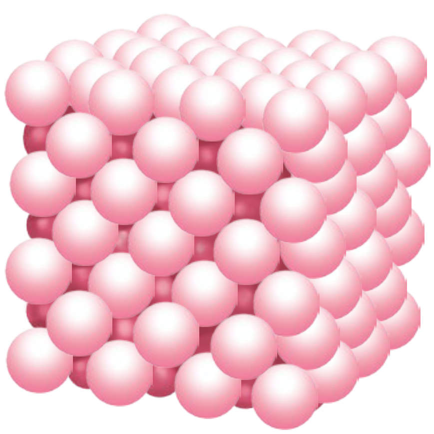


Figure 5.4: Pure gold (Au) is made of only gold atoms.

A compound is made of different elements bonded together

A **compound** is a substance made up of more than one type of atom **chemically bonded** together in a fixed ratio. Compounds can be broken down into simpler substances through chemical reactions.

Water is a compound: it is made up of water molecules, which each consist of one oxygen atom chemically bonded to two hydrogen atoms (see Figure 5.5).

Other compounds form a **lattice**, where the atoms are bonded together in a repeating three-dimensional pattern. Sodium chloride (table salt) is an example of a compound that exists as a lattice in which the sodium and chlorine atoms are in a 1:1 ratio (see Figure 5.5).

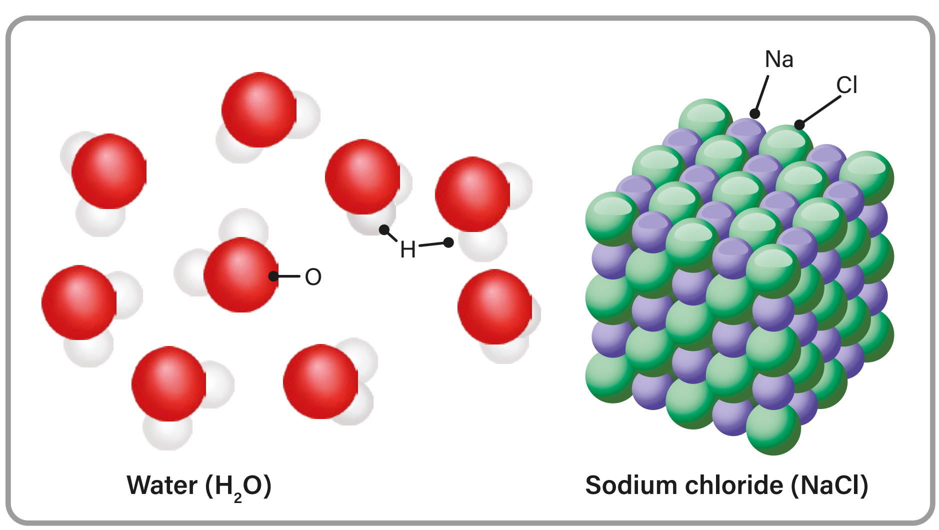


Figure 5.5: Compounds are usually molecules like water (H_2O) or lattices like salt (sodium chloride (NaCl)).

A mixture is made up of different substances that are not bonded together

Impure substances are mixtures because they consist of more than one type of particle. A **mixture** contains two or more elements and/or compounds that can be separated. Although a compound contains atoms of different elements, these cannot be easily separated because they are bonded together.

Seawater is a mixture of salt and water. If you boil seawater, the water escapes as a gas, leaving the salt behind.

Mixtures can be classified into heterogeneous and homogeneous mixtures

A **homogeneous** mixture has the same composition throughout. It is usually made up of a solvent, with one or more dissolved solutes. As the solutes dissolve, they become evenly distributed throughout the mixture. An example of a homogeneous mixture is salt water.

In a **heterogeneous** mixture, the substances are unevenly distributed. This is usually because one or more substances of the mixture are insoluble (do not dissolve). This means that different parts of the mixture have different compositions. For example, if a beaker contains a mixture of sand, water and pebbles, the sand and pebbles will settle to the bottom rather than dissolving evenly through the water. The mixture separates into layers (see Figure 5.6). So, different parts of the mixture have different compositions of sand, pebbles and water.

Suspensions and colloids are types of mixtures

Two other types of mixtures are suspensions and colloids. Their particles behave differently from the particles in solutions.

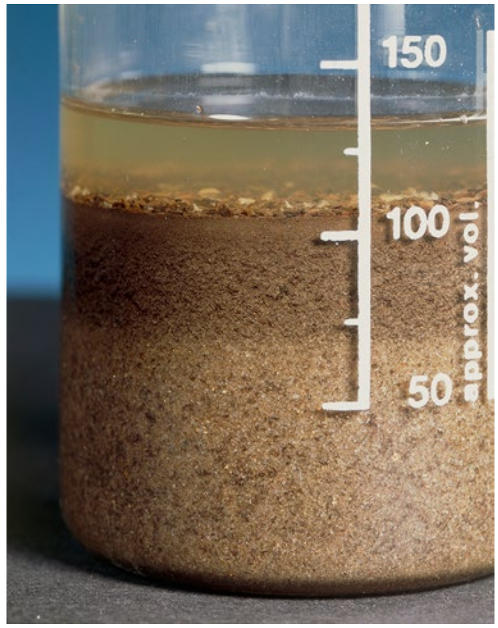


Figure 5.6: This mixture of sand, water and pebbles has separated into layers. The particles are not bonded together.

- A **suspension** is a mixture made up of large insoluble particles. At first, the particles are spread out evenly but eventually they settle to the bottom of the container. The mixture in a snow globe is a suspension: it is made up of plastic 'snow' particles mixed in water (see Figure 5.7).
- A **colloid** is a mixture made up of tiny insoluble particles. The particles are spread out evenly and never settle to the bottom of the container. Milk is a colloid: it is tiny droplets of fat mixed in water.

Figure 5.7: The mixture in a snow globe is a suspension of plastic particles in water.

There are four main types of colloids, depending on whether they are made up of solids, liquids or gases. They are summarised in Table 5.1.

Table 5.1: The four types of colloids

Colloid type	Description	Example
Sol	Solid in liquid	Milk
Emulsion	Liquid in liquid	Oil in water
Foam	Liquid in gas	Whipped cream
Aerosol	Gas in liquid or solid	Smoke, steam

You can tell whether a mixture is a solution, a colloid or a suspension by shining a light at it. Colloids and suspensions look cloudy because they scatter the light beam, whereas a solution does not. This is known as the Tyndall effect.

Figure 5.8: The Tyndall effect involves light scattering by particles in a colloid or suspension. Here, a laser beam is being shone on a glass of water containing red dye and another glass containing milk (a colloid).

Learning Ladder

Mixtures

1. Classify these substances as elements, compounds or mixtures.
   - **a** Gold
   - **b** Carbon dioxide
   - **c** Milky tea
   - **d** Soil
   - **e** Oxygen
   - **f** Water
2. Describe the difference between homogeneous and heterogeneous mixtures.

Nature and development of science

1. Propose a scientific problem related to pure and impure substances.
2. Suggest why it might be important for chemists and environmentalists to collaborate to analyse the composition of a local pond.
3. Water plants are dying in a pond containing cloudy-looking water. Propose what this evidence suggests in terms of mixtures.

Planning and conducting

p. 226

Read Investigation 5.1 (page 309).

1. Identify two pieces of equipment required for this investigation and describe how they would be used.
2. Describe how you would minimise risk when handling the equipment identified in Question 1.
3. Identify the independent (changed) variable, dependent (measured) variable and controlled variables in this investigation.
4. **a** Explain the difference between precision and accuracy.
   b Explain how digital tools could be used to generate and record data with precision.
5. You are asked to classify a variety of substances. Design an investigation that is valid, reproducible, and considers safety and ethical factors.

Key idea: Scale and measurement

Research to find out the proportions of each of the elements and compounds in Earth's air. Construct a visual that represents your suggested proportions. Refer to the Science how-to for help with ratios (page 263), graphing (page 270) and pie charts (page 273).

Success criteria

- I can distinguish between elements, mixtures and compounds and explain their properties using particle theory.
- I can identify types of mixtures.
- I can classify matter into pure and impure substances based on their particle composition.

5·2 ▸ Solute, solvent, solution

Learning intention

At the end of this lesson, I will be able to describe mixtures in terms of solute, solvent and solution.

Key terms

concentration: the amount of a dissolved solute in a defined amount of solvent

dissolve: particles separating and spreading out, so that they seem to disappear, when added to another substance

insoluble: does not dissolve

soluble: able to dissolve

solute: a substance that is dissolved by a solvent

solution: a homogeneous mixture in which one substance (the solute) is uniformly dissolved in another

solvent: a substance that a solute dissolves in

Investigation 5.2

Solutes and solvents, p. 311

Key idea: Scale and measurement

▲ **Figure 5.9:** Cordial dissolves in water to make a solution.

Mixtures are made up of two or more substances that can be physically separated. A solution is a homogeneous mixture that is made up of a solute and a solvent.

Solutes dissolve in other substances

A **solute** is any substance that can **dissolve** in another substance (the **solvent**) to form a solution. A **solution** is a homogeneous mixture in which one substance (the solute) is uniformly dissolved in another (for example, salt water in which the salt is the solute and the water is the solvent).

Solutes can begin as any of the three main states of matter:

- **Solid:** For example, sugar, salt and instant coffee are all solutes that can dissolve in water.
- **Liquid:** For example, cordial can dissolve in water to make a sweet drink.
- **Gas:** For example, carbon dioxide can dissolve in soft drinks, which makes them fizzy.

Substances that dissolve are said to be **soluble**. Substances that do not dissolve are **insoluble**.

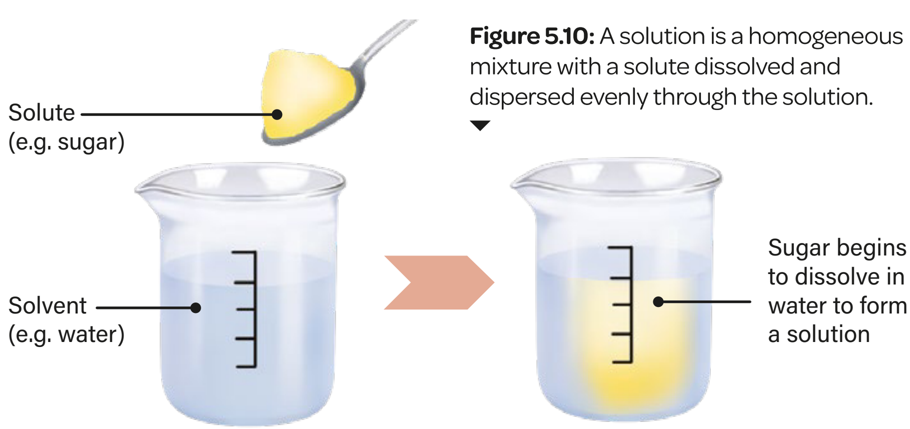
Solvents dissolve solutes

A solvent is any substance, usually a liquid, that can dissolve another substance (the solute). A soft drink is made up of cordial (a liquid), sugar (a solid) and carbon dioxide (a gas) dissolved in water (a liquid).

Some solutes will dissolve in one solvent, but not in others. For example, oil will not dissolve in water, but will dissolve in an alcohol-based solvent.

If you can see through a mixture (it is transparent), then it is a solution. For example, when copper sulfate solid dissolves in water, you get a clear but coloured solution. Some solutions are clear and colourless. For example, hydrochloric acid is a clear solution. Therefore, solutions can be coloured or colourless and are always transparent.

Figure 5.10: A solution is a homogeneous mixture with a solute dissolved and dispersed evenly through the solution. ▼



A solution is a solute in a solvent

A solution is a mixture of one or more solutes dissolved in a solvent. For example, a cup of black coffee is a solution made up of:

- solute(s): powdered coffee (and maybe sugar)
- a solvent: water.

We can calculate the concentration of a solution

We can calculate the **concentration** of a solution by dividing the mass of the solute by the volume of the solvent. Scientists commonly record concentration in grams per litre (g/L).

$$C = \frac{m}{V}$$

where: C = concentration (g/L)
m = mass (g)
V = volume (L)

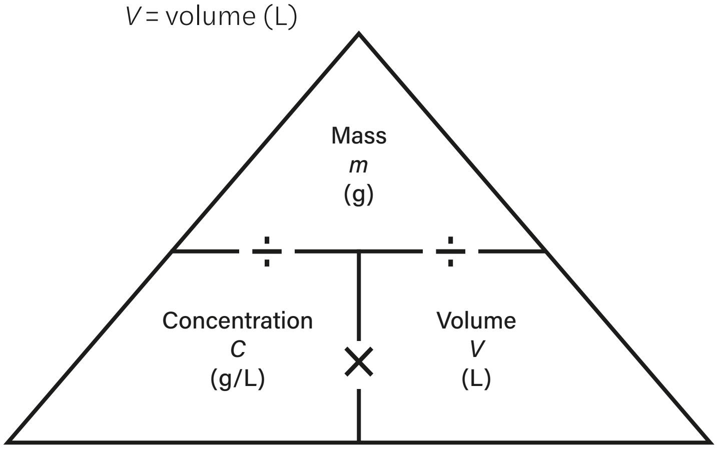


Figure 5.11: The formula triangle for calculating concentration, mass and volume. Cover up the value you are trying to work out. If the remaining two values are next to each other (e.g. C and V), multiply them. If one is on top of the other, divide the top one by the bottom one to get the answer.

Example:

What is the concentration (g/L) of a solution that contains 560 g of sugar dissolved in 2 L of water?

$m = 560$ g

$V = 2$ L

$C = \frac{m}{V}$

$= \frac{560}{2}$

$= 280$ g/L

The concentration of the solution is 280 g/L.

Learning Ladder

Mixtures

1. Identify the solute and the solvent for each solution:
   a Sweet, black tea
   b Orange juice made from powdered concentrate
   c A glass of soda water
   d Seawater
2. Describe two examples of drinks that are solutions. Justify your answer.
3. Explain how light can be used to determine if a mixture is a solution.
4. Propose a way that you could separate a solution containing water and salt.
5. Discuss why it may be important to find ways to separate salt and water.

Nature and development of science

1. Outline how you can identify whether a mixture is also a solution or not.
2. Describe why scientists from different fields should collaborate when studying solutions and their uses.

Processing, modelling and analysing p. 230

1. Identify the concentration of the solution from Example 1 on this page.
2. Construct a table that would allow you to record data about solutions to be used to calculate their concentrations.
3. **a** Input data from the example into your table from Question 2, showing the calculation used to determine concentration.
   b Create sample data of your choice for three more unknown solutions. Display the equations and mathematical process used to calculate concentration for each.

Key idea: Scale and measurement

In your house, identify two solutions used for cooking and two for cleaning.

a Predict whether each has a high or low concentration. Conduct research to evaluate your predictions.

b Explain why understanding the measurement of concentration of household solutions is important.

Success criteria

- I can describe the properties of a solution.
- I can identify solvents, and solutes in different solutions.

5·3 ▸ Properties of solutions

Learning intention

At the end of this lesson, I will be able to distinguish between concentrated and dilute solutions with respect to the solute and solvent.

Key terms

concentrated: when a solution has a large amount of solute in a certain volume

dilute: when a solution has a small amount of solute in a certain volume

saturated: a solution that cannot dissolve any more solute

saturation point: the point at which a solution has dissolved the maximum amount of solute

supersaturated: when a solution contains more than the maximum amount of solute it can normally dissolve

Investigation 5.3A

Calculating the concentrations of solutions, p. 312

Investigation 5.3B

Preparing dilutions, p. 314

Key idea: Scale and measurement

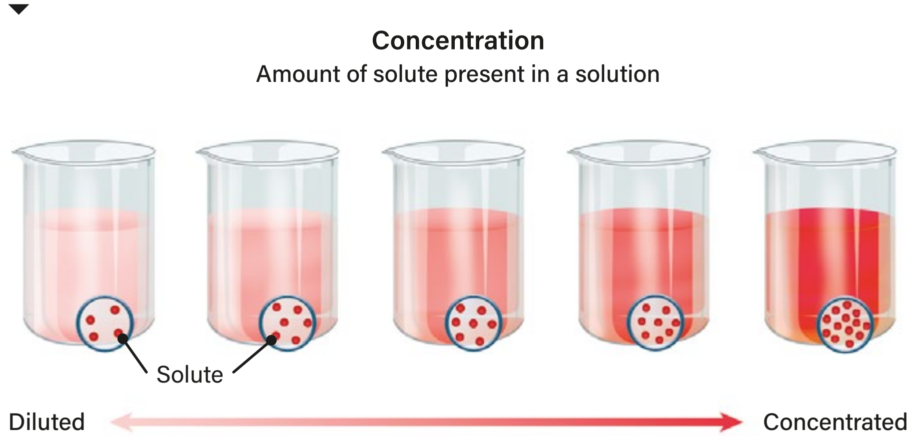
Figure 5.13: Honey is a supersaturated solution because it contains more sugar particles than can usually dissolve in water at room temperature.

Solutions are present all around us. The tea and coffee that we drink and the salt water that we swim in at the beach are all solutions! The particles of solutions interact in specific ways, meaning that they have determined properties. One of these is concentration.

Solutions can be concentrated or dilute

- A **concentrated** solution contains a lot of solute. The solute particles are close together within the solvent. For example, dissolving 20 tablespoons of cordial in a glass of water makes a concentrated (and unpleasantly sweet) solution.
- A **dilute** solution contains a very small amount of solute. The solute particles are widely spaced out within the solvent. For example, dissolving a quarter of a teaspoon of cordial in a glass of water makes a dilute (and not sweet enough) solution.

Figure 5.12: The same volume of the concentrated solution has more solute particles than the dilute solution.



Saturated solutions contain the maximum amount of solute that can dissolve

A solvent can only hold a certain amount of solute. This means that at a certain point, called the **saturation point**, no more solute can dissolve into the solution and the solution is described as **saturated**.

Heating a saturated solution can make a supersaturated solution

If we heat a saturated solution, we can dissolve more solute in it. Then, if we slowly cool the solution back to room temperature, the solute sometimes stays in solution, even at the lower temperature.

Figure 5.14: Potassium permanganate forms a purple solution in water. The more concentrated the solution, the darker the colour.

These solutions are called **supersaturated** solutions because they contain *more* solute than the solution could otherwise hold if it were made at room temperature (see Figure 5.15).

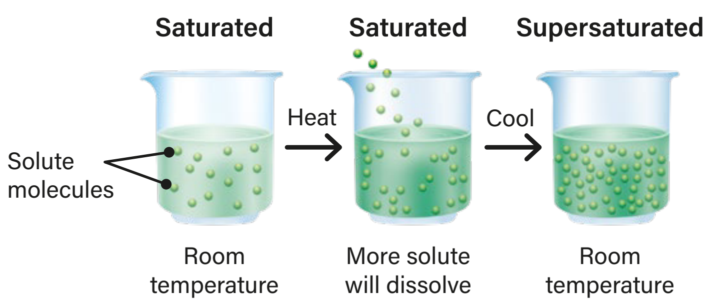


Figure 5.15: A supersaturated solution has the maximum amount of solute dissolved.

Honey is a supersaturated solution (see Figure 5.14). In making honey, the bees fan the honeycomb with their wings, which helps to evaporate water from the honey. So, honey contains more sugars than could usually dissolve at room temperature. You might have noticed that after the honey has been stored for a while, the sugars crystallise out.

Learning Ladder

Mixtures

1. Identify an example of a dilute solution that you might find in your home.
2. Describe how the particles of the solute and solvent in a concentrated cordial solution are arranged.
3. Propose and explain, using diagrams, how you could decrease the concentration of salt water.

Use and influence of science

1. **a** Propose a social problem that is addressed by increasing the concentration of chlorine in swimming pools.
   b Predict a new problem this response could create.
2. Describe how scientific knowledge of chlorine concentrations in swimming pools could impact the people in society.
3. Explain how ethical considerations might influence the regulation of chlorine concentrations in public swimming pools.

Evaluating *p. 239*

A student conducted an investigation to produce the diluted solutions shown in Figure 5.13.

1. Identify an error that may occur in this investigation.
2. Solid particles are seen settling to the bottom of one of the more concentrated solutions. Describe a type of error that may cause this.
3. The student found that more concentrated solutions were darker in colour. Explain why this might occur.
4. Create an evidence-based argument to justify the claim that less concentrated solutions had a lower mass of solute.
5. The student concluded that in all examples more concentrated solutions would be darker in colour than less concentrated solutions. Evaluate this claim.

Key idea: Scale and measurement

Swimming pools use a solution of chlorine in water to kill germs. Research the concentration of chlorine to water required and construct a visual representation of the components in pool water.

Success criteria

- I can describe escribe the concentration of solutions in relation to the amount of solute dissolved in the solvent.
- I can construct diagrams to demonstrate the amount of solute in different types of solutions.

5·4 ▸ Separating mixtures: filtration and decantation

Learning intention

At the end of this lesson, I will be able to explain how the physical properties of substances are used to separate the components of mixtures by filtration and decantation.

Key terms

decantation: the process of carefully pouring off the liquid from a mixture, leaving the sediment behind

filtrate:the liquid that passes through a filter in filtration

filtration: the process of separating a mixture of solid particles from a liquid using a filter

immiscible: cannot form a homogeneous mixture; insoluble

residue: the solid that does not pass through a filter in filtration

sediment: the solid that settles to the bottom of a liquid in a mixture

sieve: a tool with small holes used to separate solids from liquids

Investigation 5.4

Purifying muddy water, p. 315

Key idea: Scale and measurement

Mixtures can be separated into their individual components by physical means. The choice of separation method depends on the physical properties of the components and the desired purity of the separated substances.

Mixtures can be physically separated

Mixtures can contain:

- soluble substances, which will dissolve, such as salt in water
- insoluble substances, which will not dissolve, such as sand.

Scientists use information about solubility to help decide which technique to use to separate a mixture.

Filtration and decantation are two methods used to separate insoluble solids from liquid mixtures.

Filtration separates liquids from solids

Filtration is used to separate insoluble substances from liquids. The filter is a **sieve**: small holes allow the liquid to pass through but trap larger particles. So, filtration separates substances on the basis of particle size.

To make a cup of tea, we can use a strainer to filter the tea leaves. We can also use a tea bag where the tea leaves are inside the filter. Water can pass through, but the tea leaves cannot.

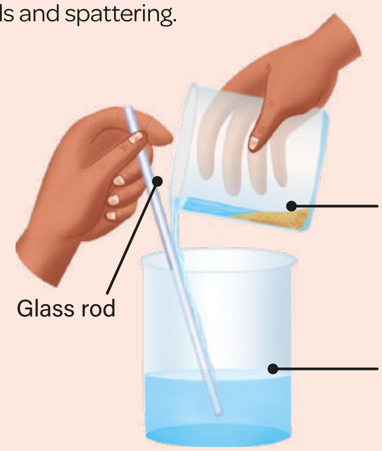
Figure 5.16 shows how to use filter paper to separate a mixture of chalk and water. The solid chalk particles get trapped in the filter paper but the liquid water passes through it. The chalk left in the filter paper is called the **residue** and the liquid that passes through the filter paper is called the **filtrate**.

Decanting separates sediments from liquids

Decantation is another method used to separate mixtures of liquids and insoluble solids. **Sediment** is

Figure 5.16: Chalk particles can be separated from water by filtering the mixture through filter paper.

Figure 5.17: After the solid sediment has settled, the liquid component of a mixture can be carefully decanted off the top. The glass rod assists when decanting by reducing spills and spattering.



the insoluble particles of a mixture that settle to the bottom of the container. When this occurs, the liquid can be slowly and carefully poured out, leaving the insoluble solid behind, as shown in Figure 5.17.

Decanting is used in the process of making cheese. As the cheese forms, the remaining milk 'floats' to the top and is skimmed off.

When two liquids are combined but cannot dissolve to form a homogeneous mixture, it is called an **immiscible** mixture. This mixture can also be separated by decanting. Two immiscible liquids of different densities (e.g. oil and water) will form two layers. The property that allows this separation is density. The less dense liquid could be 'skimmed' off the top, making sure not to disrupt the layer below. However, a better way to separate immiscible liquids is by using a separating funnel, as shown in Figure 5.18.

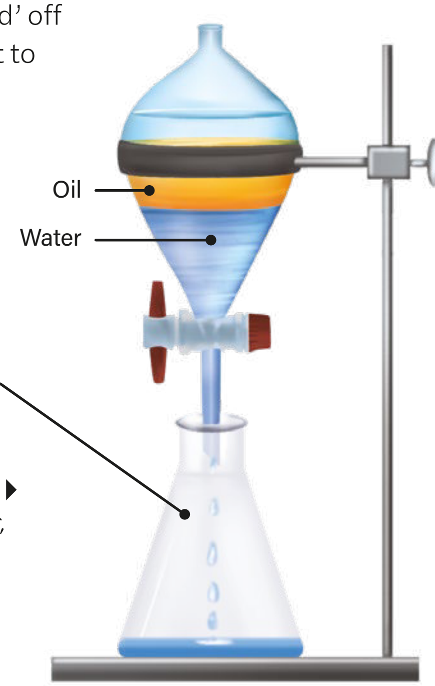


Figure 5.18: Two immiscible liquids, such as oil and water, can be put into a separating funnel and left to settle into layers. When the tap is opened, the liquid at the bottom runs into the flask.

Learning Ladder

Mixtures

1. You use filtration to separate a mixture of sand and water. Identify the:
   a residue. **b** filtrate.
2. Describe a property of a chalk and water mixture that makes it suitable for separation by filtration.
3. Describe the process of filtration and construct a diagram to illustrate it.
4. Outline the steps you would take to separate a mixture of oil, water and gravel. Explain the purpose of each step in relation to the components of the mixture.
5. Discuss the importance in society of using filtration and decantation. Refer to specific examples.

Nature and development of science

1. Propose how muddy water could be a scientific problem.
2. Propose two fields of science that could collaborate to improve the effectiveness of water purification methods such as filtration and decantation.
3. Propose a new observation that could be made when filtering muddy water. Discuss how it could contribute to improving the design of water-purifying equipment.

Planning and conducting *p. 226*

Refer to Investigation 5.4 on page 315 to answer the following questions. Read the aim, materials and method.

1. Identify the order in which each of the items in the materials list will be used in this investigation.
2. Select two pieces of equipment used.
   a For each piece of equipment, identify two hazards.
   b Describe how you would minimise the risks for each of these hazards.
3. Identify the independent (changed) variable, dependent (measured) variable and at least three controlled variables in this investigation.

Key idea: Scale and measurement

LifeStraw™ is a brand of straw filter made for people going hiking or camping so they can safely drink water from contaminated sources. Discuss how the scale (size) of possible contamination particles in water sources should compare to the specifications of the LifeStraw™ filtration design.

Success criteria

- I can describe the processes of filtration and decantation.
- I can identify the appropriate separation method to use for different mixtures.

5·5 ▸ Separating mixtures: evaporation, crystallisation and distillation

Learning intention

At the end of this lesson, I will be able to explain how the physical properties of substances are used to separate the components of mixtures by evaporation, crystallisation and distillation.

Key terms

condensation: a change of state from gas to liquid

condenser: a glass tube cooled by water that cools a gas to become a liquid

crystallisation: the separation of a solution by evaporating the solvent, leaving behind solute crystals

desalination: the process of removing dissolved salts from seawater

distillation: the separation of liquids with different boiling points by evaporation and condensation

evaporation: a change of state from liquid to gas

Investigation 5.5A

Evaporating a solution, p. 317

Investigation 5.5B

Growing crystals, p. 318

Investigation 5.5C

Demonstrating distillation, p. 319

Key idea: Scale and measurement

Australia experiences frequent droughts and water shortages. Although we are surrounded by oceans, we (like many other living things) cannot survive on salt water. But we can separate the salt from the water. **Desalination** is a process that uses the separation techniques of evaporation, crystallisation and distillation to purify salt water.

Solids can be crystallised out of solutions

Evaporation is the change of state from liquid to gas. It can be used to separate a mixture such as salt water by evaporating the liquid to leave the salt behind. This happens slowly at room temperature. Evaporation can be sped up by heating the solution in an open container such as an evaporating basin.

When most of the liquid has evaporated, the salt will start to form crystals; this is called **crystallisation**. Smaller crystals form if the liquid evaporates quickly, and larger crystals form if it evaporates slowly.

Crystallisation is used on a large scale to separate sea salt from seawater. The water is evaporated off to leave behind crystals of sea salt (see Figure 5.19). The salt crystals can then be used in cooking, in products such as body scrubs, or as a preservative so that food can be stored for longer periods of time without spoiling.

Distillation can purify water

Salt water can also be separated by **distillation** (see Figure 5.20). First, the salt water is heated in a glass flask and the water evaporates off. The water vapour is captured and cooled in a tube called a **condenser**, which has cool water flowing around it. This causes the gas to change back to a liquid. This change is called **condensation**. The condensed liquid (purified water) is collected in a different container, while the salt crystals remain in the flask.

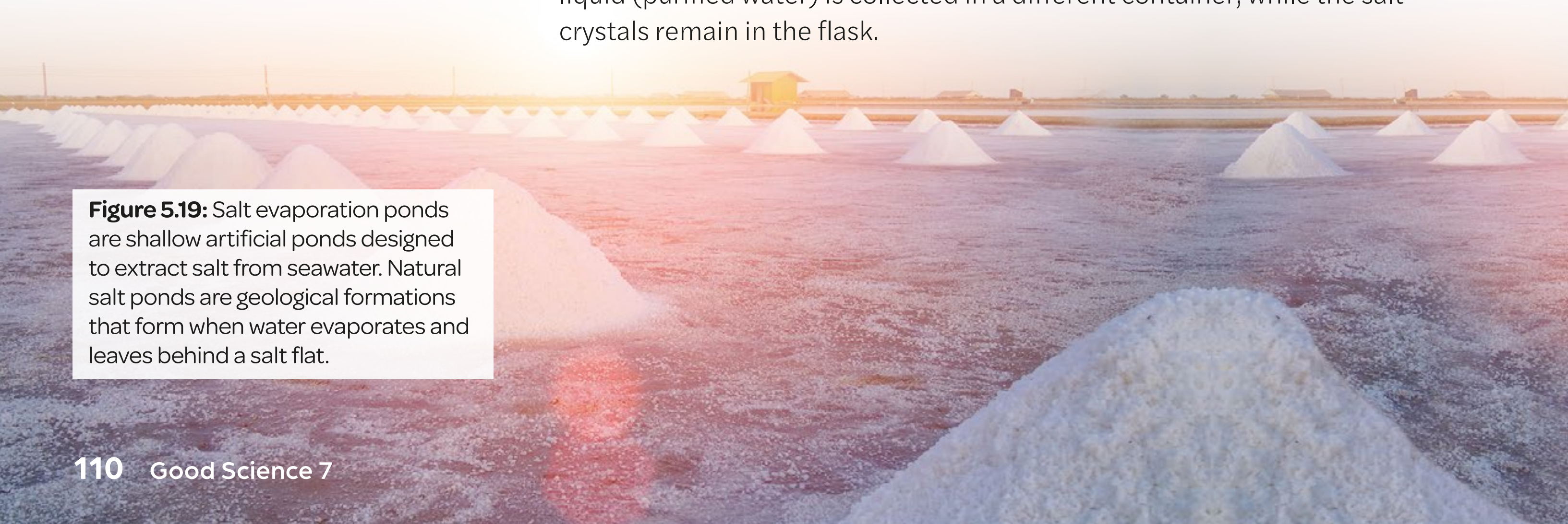


Figure 5.19: Salt evaporation ponds are shallow artificial ponds designed to extract salt from seawater. Natural salt ponds are geological formations that form when water evaporates and leaves behind a salt flat.

Distillation can also be used to separate two liquids, such as water and alcohol. The physical property that allows these substances to be separated is boiling point. Every substance has a different boiling point and the substance with the lower boiling point boils off first. In the example of water and alcohol, alcohol has a lower boiling point, so it evaporates and condenses, leaving the water in the flask, as shown in Figure 5.20.

Some everyday items contain solutions produced by distillation. Cars run on refined oil, which must be distilled as part of its purification process. Many perfume scents are collected through the process of distillation.

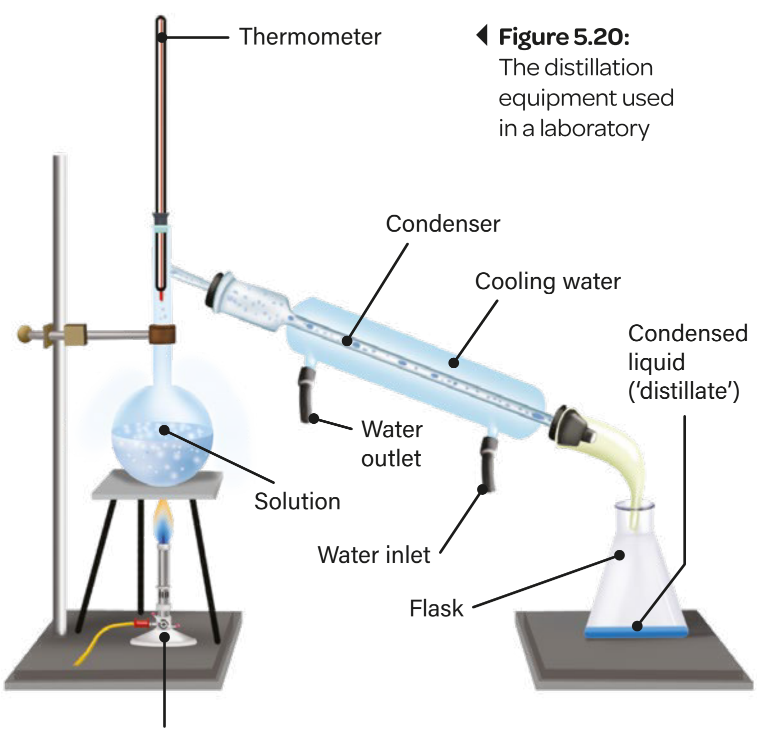


Figure 5.20: The distillation equipment used in a laboratory

Learning Ladder

Mixtures

1. Identify the physical property of a substance that is used to separate mixtures in distillation.
2. Describe the relationship between evaporation and crystallisation. Propose an example of a mixture that can be separated by evaporation and crystallisation.
3. Explain how you could produce large crystals when separating a mixture by evaporation and crystallisation.

Use and influence of science

1. Propose an environmental issue related to using the process of evaporation to obtain salt.
2. Propose how desalination, using evaporation and crystallisation, can impact society.
3. Explain how ethical, environmental and economic considerations influence the use of desalination techniques.
4. Discuss how the responses to water scarcity, such as using desalination methods, can affect local communities.
5. Propose and evaluate how communication about desalination techniques influences people's views on water scarcity.

Processing, modelling and analysing *p. 230*

An evaporation investigation was conducted to determine the relationship between temperature and the size of crystals formed. Salt water heated to 25 °C evaporated after 180 minutes and produced a crystal size of 0.5 mm. The same solution heated to 80 °C evaporated after 60 minutes and produced a crystal size of 0.2 mm.

1. Identify the temperature that produced the larger crystals.
2. Construct a table to organise the given information, including appropriate headings and units.

Key idea: Scale and measurement

Research the desalination process, including measurements and quantities. Discuss the purpose of a desalination plant. Explain the role of distillation in the desalination process, including reference to scale and measurement.

Success criteria

- I can describe the difference between evaporation, crystallisation and distillation.
- I can give examples of situations in which each technique could be used to separate substances.

5·6 ▸ Separating mixtures: magnetic separation, paper chromatography and centrifugation

Learning intention

At the end of this lesson, I will be able to explain how the physical properties of substances are used to separate the components of mixtures by magnetic separation, paper chromatography and centrifugation.

Key terms

centrifugation: a technique for separating the components of a mixture on the basis of their different densities

magnetic separation: a process that uses magnets to separate magnetic materials from non-magnetic ones in a mixture

paper chromatography: a technique that separates the components of a mixture based on their solubilities

Investigation 5.6

Separating colours in dyes by paper chromatography, p. 321

Key idea: Scale and measurement

Magnetic separation separates magnetic from non-magnetic materials

Magnetic separation is a process that uses magnets to separate magnetic materials from non-magnetic ones in a mixture. Magnetic materials are substances that are attracted to a magnet and can be magnetised themselves. These materials typically contain iron, nickel, cobalt or certain rare earth metals.

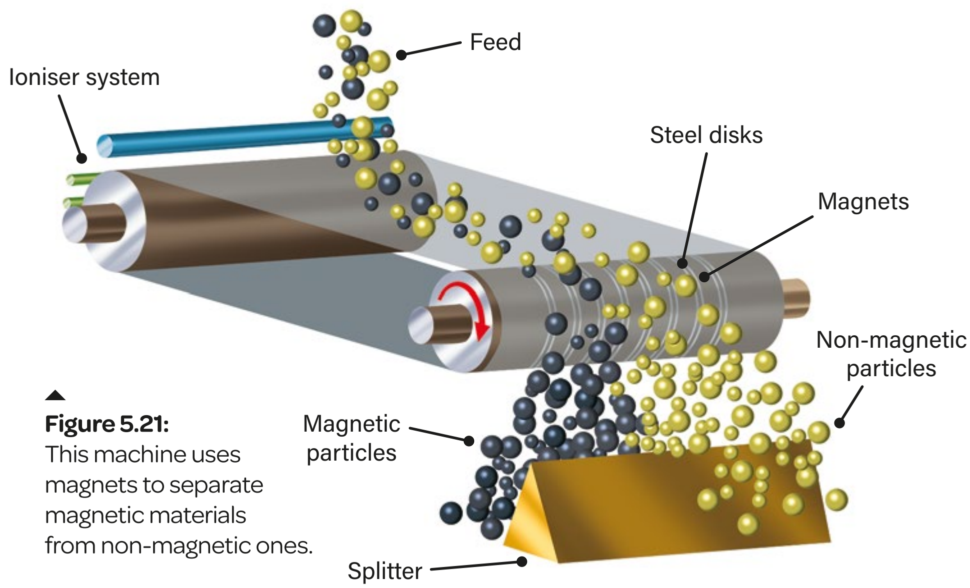
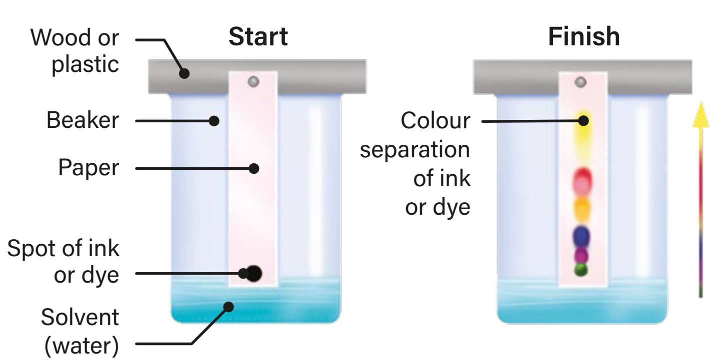


Figure 5.21: This machine uses magnets to separate magnetic materials from non-magnetic ones.

In a recycling plant, magnetic separation is used to remove iron and steel cans from a pile of mixed waste. A strong magnet attracts the magnetic metals, pulling them out, while non-magnetic materials such as plastic and glass are left behind. This method works because iron and steel are magnetic, while materials like plastic, paper and glass are not.

Figure 5.22: Paper chromatography separates the black ink into its coloured components. The yellow spot moves up the furthest. The green component moves the least distance because it is the least soluble.



Paper chromatography separates dyes based on solubility

Paper chromatography is used to separate the components of mixtures of soluble substances on the basis of their solubility. The components are often coloured, such as inks or dyes (see Figure 5.22).

A mixture is dissolved in a liquid to make a solution. A drop of the solution is placed at one end of a piece of chromatography paper, which is then placed in a solvent (for example, water). The solvent moves up

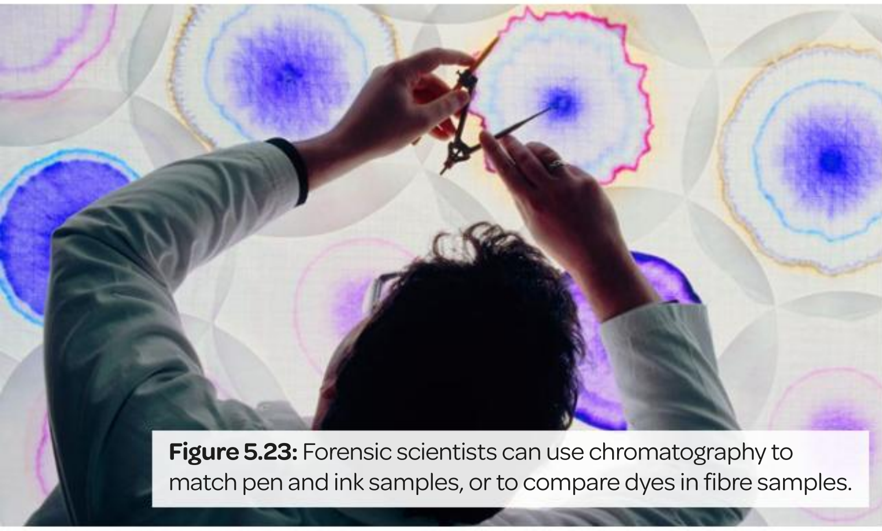


Figure 5.23: Forensic scientists can use chromatography to match pen and ink samples, or to compare dyes in fibre samples.

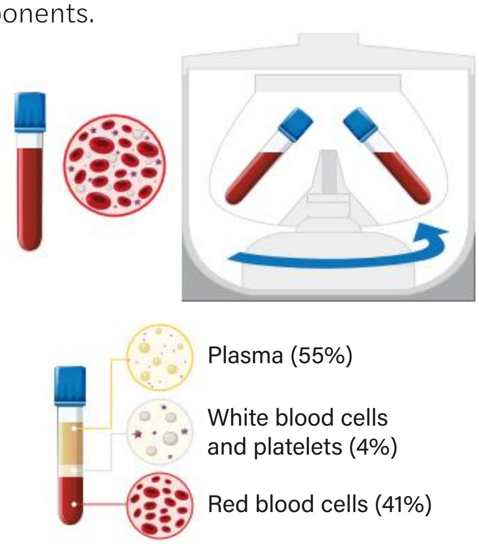
the paper, carrying the dissolved substances with it. The most soluble substances move the furthest. Other substances are less soluble so do not move as far. In this way, the components of the mixture are separated.

Chromatography is used in industry to analyse substances found in oils and gases and to identify pollutants in the environment. In the pharmaceutical industry, chromatography can be used to test the effectiveness of medicinal substances that originated from animals and plants.

Centrifugation separates the components of a mixture by density

Centrifugation is a technique that uses centrifugal force to separate components of a mixture on the basis of their densities. The mixture is spun at high speeds in a centrifuge, causing the denser components to move to the bottom of the container. For example, we can use centrifugation to separate blood into its different components.

Figure 5.24: Centrifugation of blood separates it into red blood cells, plasma, and white blood cells and platelets



Learning Ladder

Mixtures

1. Identify which mixture could be separated by centrifugation.
   A Alcohol and water **B** Blood
   C Sugar and water **D** Muddy water
2. Describe the physical properties of substances that allow them to be separated by:
   a centrifugation. **b** chromatography.
   c magnetic separation.

Nature and development of science

1. Propose a problem that has been solved by centrifugation.
2. Describe how physicists studying magnets and scientists working to recycle waste may need to collaborate.
3. Explain how new evidence from the centrifugation of blood may have led to changes in scientific knowledge.
4. Discuss how our knowledge of the chemicals in coloured dyes may have developed with the invention of chromatography.
5. Discuss how different scientists may have collaborated to develop the knowledge used by forensic scientists.

Planning and conducting *p. 226*

Refer to Investigation 5.6 (page 321). Read the aim, materials and method before answering the questions below.

1. Identify which of the following sets of equipment are required to conduct this investigation.
   A Beaker, filter paper, tape
   B Watch glass, eyedropper, filter paper
   C Magnifying glass, thermometer, test tube
   D Stopwatch, pH meter, microscope
2. **a** Identify two hazards in this investigation.
   b Describe two ways to minimise these risks.
3. Identify the independent, dependent and controlled variables.

Key idea: Scale and measurement

Blood is a mixture with four main components: red blood cells, platelets, plasma, and white blood cells. Conduct research into the proportion of these components and construct a visual representation of your findings.

Success criteria

- I can explain how the physical properties of substances enable them to be separated by magnetic separation, paper chromatography and centrifugation.

5.7 ▸ First Nations Peoples' separation techniques

Learning intention

At the end of this lesson, I will be able to describe the different ways that mixtures have been separated by First Nations Peoples.

Key terms

coolamon: a shallow dish traditionally used by First Nations Peoples to carry water and food and for winnowing seeds

hand picking: a simple method of separating a mixture of objects

leaching: a method of removing soluble substances by the action of water passing through the material

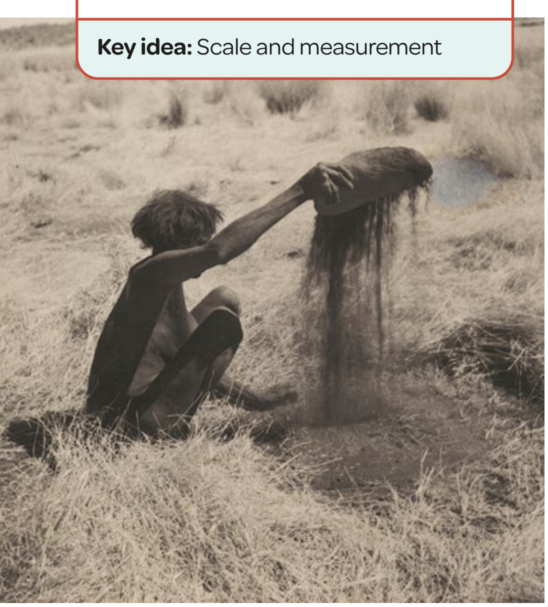
sieving: using a sieve to separate larger particles from smaller particles

toxin: a poisonous substance produced by a living thing

winnowing: separating a mixture of seeds and husks by blowing air through the mixture

yandying: separating less dense particles from denser ones

Key idea: Scale and measurement



▲ **Figure 5.25:** This woman is using a coolamon to winnow seeds from other material. A coolamon is a traditional wooden object used for carrying various things.

In Australia, First Nations Peoples have used ecology, agriculture, aquaculture and animal husbandry to care for Country and to grow foods that are easy to cultivate and prepare for eating.

First Nations Peoples have used their knowledge of science and specific techniques to separate edible parts from inedible – and sometimes toxic – parts of plants or food.

Hand picking is a simple method of separating objects

First Nations Peoples have used eucalyptus leaves for thousands of years to ease coughs and colds. Some species are considered to have antifungal, antibacterial and mosquito-repellent properties. When brewing a gum leaf tea for medicine, the desired leaves are usually a lighter green and smaller than the older leaves. The leaves can be easily separated by **hand picking**.

Sieving separates particles of different sizes

Sieving is a common process of using a sieve or another object to separate larger particles from smaller particles. First Nations Peoples sometimes use sieving to catch small freshwater fish and yabbies in creeks and rivers. They hold vegetation and foliage while walking in a line across a creek to sieve the water. The water passes through the vegetation, and the fish and yabbies are caught in the vegetation.

Winnowing separates objects of different masses and densities

This separation technique is especially effective when there are two or more objects that have different masses and densities. **Winnowing** has been commonly used by First Nations Peoples to separate the heavier edible seeds of native grasses from their lighter and inedible husks. The tool used is a **coolamon**. The seeds and husks are thrown into the air. The wind blows away the husks, and the heavier seeds fall back into the container (see Figure 5.25).

Winnowing has been a key part of the process for First Nations Peoples to make flour and bake bread.

Figure 5.26: This coolamon is being used to yandy seeds and chaff (seed coverings) through movement. Their different densities mean that they will form two groups with the movement and be easier to separate.

Yandying separates objects of different masses and densities

Yandying also relies on objects having different masses and densities. It involves moving a coolamon in particular ways to separate the objects. The coolamon is held with one corner raised up. It is then gently shaken to force the smaller and denser particles to collect at the bottom. The larger and less dense particles stay higher up.

Some First Nations Peoples (such as the people of the Pilbara region of Western Australia) use yandying. A coolamon can be modified to separate particles of tin from soil.

Leaching uses running water to remove toxins

Leaching is a less common separation technique for making food sources safe to eat by removing soluble **toxins**. For example, across the northern parts of Australia, some First Nations Peoples eat the seeds from the cycad plant. The seeds must be treated to remove toxic substances before being eaten.

A common way of treating the seeds is by **leaching** out the toxins in running water. The seeds are placed into slow-moving water. Over time, the toxins leach from the seeds and dissolve in the water. The toxins are washed away in the moving water and the seeds can be cooked and eaten.

Figure 5.27: Cycad seeds on the tree ready for harvesting. The seeds contain toxic substances that can be removed by leaching.

Learning Ladder

Mixtures

1. Identify the components being separated from the mixture in Figure 5.25.
2. Describe the process of hand picking.
3. Explain the properties of a mixture that are needed for winnowing to be an effective separation technique.
4. Propose which process could be used to separate many types of seeds. Provide a reason for your response.
5. Consider products that you use every day that need to be separated. Propose two that could be separated by each of the following techniques.
   - **a** Hand picking
   - **b** Sieving
   - **c** Winnowing
   - **d** Yandying
   - **e** Leaching

Nature and development of science

1. Identify one problem that First Nations Peoples identified and explain how they solved it with a separation technique.
2. Describe why winnowing has been an important process to enable the baking of bread in Australia.

Processing, modelling and analysing *p. 230*

1. List the five separation techniques used by First Nations Peoples that are discussed in this section.
2. Select one of the techniques that requires multiple steps and construct a flow chart to outline the process.

Key idea: Scale and measurement

Imagine you have been given a container with a mixture of soil and rocks of different sizes and densities. Explain an appropriate way to separate the mixture using techniques of First Nations Peoples.

Success criteria

- I can describe the different techniques used by First Nations Peoples to separate mixtures.
- I can select appropriate techniques used by First Nations Peoples to separate different mixtures.

5·8 ▸ Industrial separation techniques

Learning intention

At the end of this lesson, I will be able to describe the industrial applications of water purification and sewage treatment.

Key terms

disinfection: a method of destroying bacteria, often using special light or chlorine

sewage: semi-liquid human waste

sewerage: a system of pipes that carry sewage

Key idea: Scale and measurement

Many separation techniques are used on a large scale by industry. This means large quantities of materials can be separated at one time. These separation techniques are often applied to water, in order to purify contaminated water sources, so that the water is able to be reused or released safely back to the environment.

Purification makes water safe to drink

Before water is safe for us to drink, it must be purified. This involves killing bacteria and removing harmful substances. In Australia, there are six main steps in water purification (see Table 5.2). When the water is safe to drink, it is distributed through pipes to homes, schools, hospitals, businesses and many other locations.

Table 5.2: The steps involved in water purification

Step	Description
1 Screening	Water passes through mesh screens to remove objects such as twigs and leaves.
2 Flocculation	A chemical called alum is added to the cloudy water to make the small floating particles clump together. These clumps are called floc.
3 Sedimentation	The floc is heavy and settles to the bottom of the tank to form a sediment. This sediment is collected as sludge.
4 Filtration	The water flows through tightly packed beds of different-sized pebbles, sand and crushed coal to trap and remove any remaining floc and other impurities.
5 Chemical treatment	Chemicals are added to the water, such as: ▪ fluoride to help prevent tooth decay ▪ chlorine to kill harmful organisms such as bacteria ▪ other chemicals to reduce the acidity of the water.
6 Aeration	Oxygen is added to improve the smell and colour.

Figure 5.28: A water treatment plant has many different sections for the different stages, such as chemical treatment and aeration.

Sewage is processed to reduce harm to the environment

Sewage is semi-liquid human waste. When we flush a toilet, the sewage goes into a **sewerage** system and is treated.

Some countries do not have proper sewerage systems (see Figure 5.29). Untreated sewage is harmful to human health and the natural environment, so in more economically developed countries is processed before release. In Australia, there are six main steps in sewage treatment (see Table 5.3).

Figure 5.29: In some less economically developed countries, human waste goes into open sewers and is not treated.

Table 5.3: The steps involved in treating sewage

Step	Description
1 Sewerage	A network of pipes moves sewage from homes and businesses to sewage treatment plants.
2 Screening	Screens at the plant act as a sieve and catch large objects, which are physically removed.
3 Aeration	Air is pumped into tanks that hold the sewage. This feeds bacteria, which break down the sewage.
4 Settling	Other chemicals are added that cause the bacteria and solids to settle to the bottom of the tank as thick sludge. This sludge is removed and is used in soil and fertiliser products.
5 Filtration	The sewage passes through a filter made of pebbles. This traps more solids, which are removed.
6 Disinfection	Ultraviolet light or chlorine is used to kill harmful bacteria in the sewage.

After the final **disinfection** stage, the water is considered to be 'safe'. This water is then released back into the environment, where it re-enters the natural water cycle.

Learning Ladder

Mixtures

1. Identify whether untreated water is a mixture or a pure substance. Provide a reason.
2. Describe the composition of water and sewage before treatment.
3. Explain how components of sewage are separated based on their properties.
4. Compare the processes of screening and settling in sewage treatment.
5. A person is camping near a river and has run out of water. Discuss ways that they could purify river water to make it safer for drinking, and whether this is a good idea.

Use and influence of science

1. The lack of proper sewage treatment in some countries creates health and environmental problems. Propose an example of a problem.
2. Describe how scientific knowledge about water purification and sewage treatment has helped to improve public health and reduce environmental harm in Australia.
3. Explain ethical factors related to developing countries that do not have access to scientific advances in water treatment.

Evaluating

p. 239

1. In an investigation where water is being purified using the six main steps involved in treating sewage, identify whether each of the following assumptions could lead to errors in the process.
   - **a** assuming that all sewage from homes and businesses requires treatment
   - **b** assuming that screens at the plant are not damaged
   - **c** assuming that all of the bacteria and solids settle to the bottom in step 4
   - **d** assuming there is still bacteria left in the treated sewage before step 6.
2. Describe each error you identified in Question 1 as personal, random, or systemic. Explain your reasoning.

Key idea: Scale and measurement

Conduct research about the proportions of different components that make up sewage or untreated water. Construct a pie chart to display your findings. Refer to the Science how-to on page 273 if you need more information.

Success criteria

- I can describe water purification and sewage treatment as examples of industrial separation processes.

5.9 ▸ Cleaning up oil spills

Learning intention

At the end of this lesson, I will be able to apply my understanding of separation techniques to purify contaminated water.

Key terms

crude oil: oil that has not been separated into usable petroleum products

oil slick: a thin layer of oil on the surface of water

Investigation 5.9

Purifying oily water, p. 322

Key idea: Scale and measurement

Oil is one of the most important materials used today. When refined, it fuels the engines of vehicles, powers factories to produce electricity and is an ingredient in the manufacture of plastics. However, its extraction, transport and use have an impact on the environment. The accidental release of crude oil into the environment is called an oil spill. Oil spills in the ocean are very harmful to ecosystems. Understanding the properties of oil and how it mixes with water and other chemicals has allowed scientists to work out methods to clean up oil spills. This ensures that we do not contaminate water sources in the environment for extended periods of time.

Oil spills can be caused by different incidents

Oil spills in the marine environment can have different causes.

- **Crude oil** is extracted by drilling it from reservoirs underground. Often this is done from oil rigs in the oceans. If an accident happens during the drilling or pumping process, crude oil can be released into the ocean.
- Ships use oil as fuel. If a ship breaks down, runs aground, collides with another ship or has its tanks damaged, the oil can leak into the water.
- Oil is transported by massive ships called oil tankers. If these ships are damaged, the oil they are carrying can spill into the environment.

Oil spills can damage the environment

When oil is spilled into the ocean, it forms a thin layer on the surface known as an **oil slick**. Over time, the oil slick spreads out to cover a large area. If it reaches the shoreline, the oil will stick to and mix in with sediments like sand, and can kill wildlife in the ocean and on the shore.

The oil on the surface of the ocean stops oxygen and carbon dioxide gas in the atmosphere from dissolving into the water. If the levels decrease enough, this can kill marine plants and animals.

Figure 5.30: Floating booms are used to contain oil spills on the surface of water. The oil can then be skimmed from the surface.

Oil spills can be contained and filtered

Oil slicks float on top of water because oil and water do not mix, and oil is less dense than water. There are several ways that oil slicks can be cleaned up by taking advantage of these properties.

Floating booms are used to contain oil slicks. Devices called skimmers are then used to scoop or suck oil from the surface of the water within the enclosed areas. This oil can then be processed in a factory to remove any seawater that was also collected.

Sorbent booms are a special type of boom that work in a similar way to a disposable nappy, but they only absorb oil. The booms can then be removed and disposed of.

Oil on the shoreline can be difficult to clean up. One way to clean oil from the shoreline is to wash the oil back into the water so that it can be easily skimmed off the top. Another way is to remove the contaminated sediment. This is either disposed of in landfill or processed in factories to separate the oil from the sediment.

Figure 5.31: Birds caught in oil spills can lose their ability to fly, swim and float. They can also be poisoned by the oil when they try to clean themselves.

Learning Ladder

Mixtures

1. Identify whether crude oil is a pure substance or a mixture. Provide a reason.
2. Complete the sentence:
   When oil is spilled into the ocean, it forms an _________ _________ on the surface. Oil floats on water because it is _________ (more/less) dense and _________ (does/doesn't) dissolve in or mix with water.
3. Explain how oil spills can be contained and cleaned.
4. Compare the properties of oil and water that allow them to be separated.
5. Using your knowledge of separation techniques, discuss how a leak of cooking oil into a creek may be cleaned up.

Use and influence of science

1. Identify two socio-scientific issues associated with extracting oil. Provide an example of each.
2. Describe how scientific knowledge about the properties of oil has influenced our response to accidents and mishaps in the oil industry.

Evaluating p. 239

Refer to the contaminated water sample in Investigation 5.9 on page 322 to answer the following questions.

1. Identify errors or assumptions that might arise from shaking the separating funnel during the oil and water separation process. Describe how these could impact the results of the separation.
2. **a** Describe the difference between an error in the method and a mistake.
   b Describe the types of mistakes that could occur during the separation process using the funnel. Discuss how they might affect the investigation.

Key idea: Scale and measurement

In December 2024, a significant oil spill occurred in the Kerch Strait, in Europe, involving two oil tankers.

a Research this incident and determine the components and properties of the oil that was spilled.

b Compare the scale of the spill with other major oil spills (such as Deepwater Horizon in 2010).

c Outline the efforts made to clean up the spill. Propose how the success of these efforts was measured.

Success criteria

- I can outline the causes of oil spills.
- I can apply my knowledge of separation techniques to explain how to clean up oil spills.

5·10 ▸ Key idea: Scale and measurement

Learning intention

At the end of this lesson, I will be able to determine the volume and mass of objects and calculate their density using the formula $d = \frac{m}{V}$.

Key term

density formula: $d = \frac{m}{V}$ (unit: g/mL)

Investigation 5.10

Calculating density, p. 323

Key idea: Scale and measurement

Density is a measure of how much matter packs into a space. This affects whether a substance floats or sinks in water. Materials such as wood, feathers, rubber and styrofoam float, whereas rocks, glass and metal sink. To calculate density, you need to know the volume and mass of objects.

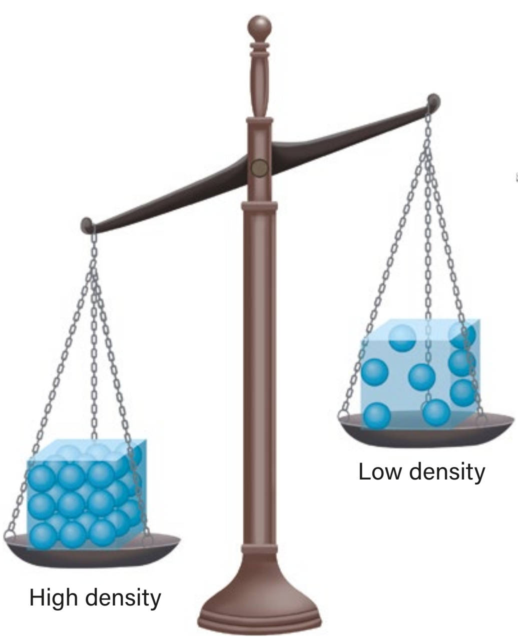
Density is the amount of matter in a certain volume

Density is a physical property that measures how much matter packs into a specific volume. The volume is measured in millilitres (mL) and mass is measured in grams (g). One kilogram of cotton weighs the same as 1 kilogram of rocks. However, their densities are different because their volumes are different. The particles in cotton are more spaced out than the particles in the rocks, so the cotton has a higher volume and a lower density.

Therefore, density is the amount of mass per unit volume. In Figure 5.32, the object with lower density has fewer particles, so it has less mass, whereas the object with higher density has more particles, so it has more mass.

If an object is less dense than water, then it will float. If the object is denser than water, then it will sink.

Figure 5.32: Two objects with the same volume may have different densities depending on the amount of matter they contain.



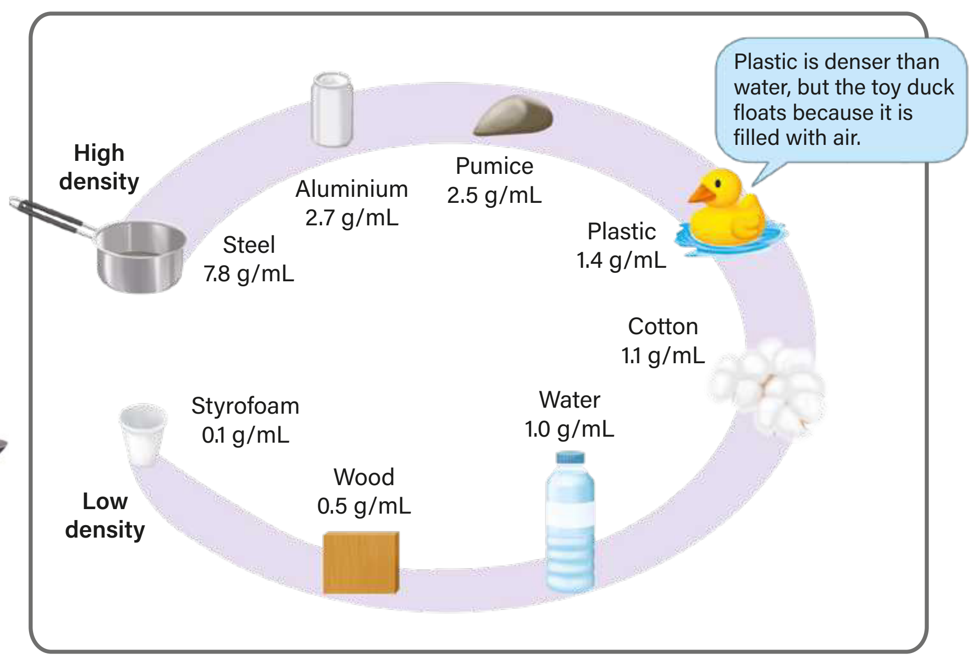


Figure 5.33: Density is a measure of how much mass is in a given volume of a material.

Density equals mass divided by volume

Density is measured in grams per millilitre (g/mL). This means that the units for volume and mass determine the units for density. The mass in grams determines the amount of the substance, and the volume determines the space taken up.

In the laboratory, mass can be measured using electronic balances and volume using a measuring cylinder.

Density is independent of quantity and shape. This means that regular-shaped and irregular-shaped objects could have the same density even though their masses and volumes are different. For example, a steel cube that weighs 7.8 grams and has a volume of 1 millilitre has a density of 7.8 g/mL. A steel nail could have the same density when its volume is 1.6 millilitres and its mass is 12.5 grams.

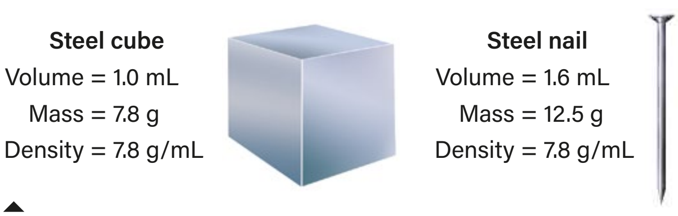


Figure 5.34: This steel cube and steel nail have the same density.

Density can be calculated by using a formula

We can use the **density formula** to calculate density:

$$d = \frac{m}{V}$$

where d = density (g/mL)

m = mass (g)

V = volume (mL)

(If mass is given in kilograms and volume is given in litres, then convert to grams and millilitres by multiplying by 1000.)

Example:

Calculate the density of a cube with mass 5 g and volume 10 mL.

$$d = \frac{m}{V}$$

$$= \frac{5}{10}$$

$$= 0.5 \text{ g/mL}$$

For more information on calculating density, see page 275 of the Science how-to section.

Learning Ladder

Mixtures

1. Determine which of the following objects has a greater density by using $d = \frac{m}{V}$.
   A A wooden log with a mass of 500 g and a volume of 2000 mL
   B A metal bar with a mass of 1.5 kg and a volume of 500 mL
2. Propose whether the log and metal bar from Question 1 would float or sink in water. (*Hint:* The density of water is 1 g/mL.)
3. Explain why it is easier to float in seawater (density 1.03 g/mL) than in fresh water (density 1 g/mL).

Use and influence of science

1. Identify which of the following issues could be related to density and provide a reason for your response.
   A There are very few organisms in the Dead Sea because the salt concentration is so high.
   B Boats do not operate properly in the Dead Sea because they become too buoyant.
2. Describe how density is related to socio-scientific issues such as oil spills, plastic pollution, air pollution or ship design.
3. Discuss how density is related to a separation technique you have learnt about.

Processing, modelling and analysing *p. 230*

A scientist studying three different liquids (A, B, and C) records the following data:

- **Liquid A:** Mass = 150 g, volume = 100 mL
- **Liquid B:** Mass = 250 g, volume = 125 mL
- **Liquid C:** Mass = 180 g, volume = 120 mL

1. Identify:
   a the liquid with the greatest mass
   b without calculating, which liquid you think will have the greatest density.
2. Construct a table to display the above data.
3. Add a column to your table and use it to calculate the density of each liquid.
4. Classify the liquids as low density (less than 1 g/mL) or high density (1 g/mL or more).
5. Analyse the data in your table and identify and explain one pattern, trend or relationship.

Success criteria

- I can describe the relationship between mass, volume and density.
- I can apply the formula $d = \frac{m}{V}$ to determine the density of substances.
- I can compare the density of different substances.

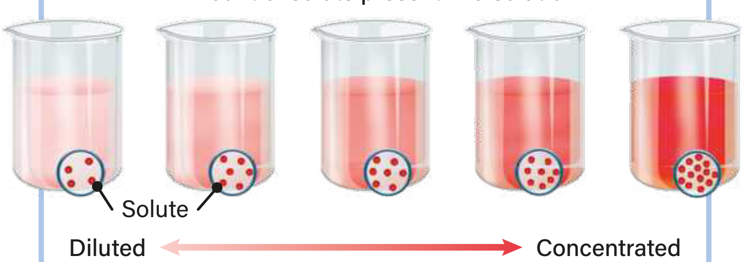
Summary

Mixtures can be separated based on the properties of their components using a variety of separation techniques:

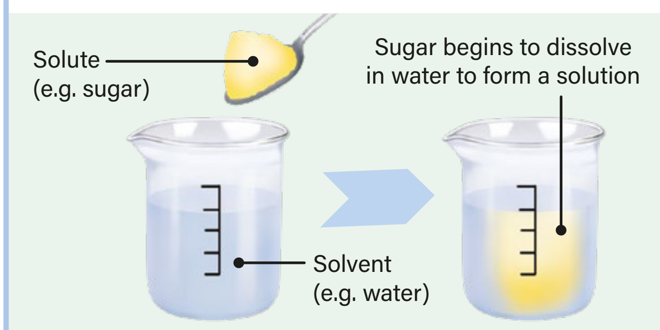
- **Decanting and filtering** can separate insoluble mixtures by using the density and size of the particles.
- **Evaporation and crystallisation** can separate dissolved solids from water or other liquids.
- **Distillation** can separate two liquids with different boiling points.
- **Magnetic separation** divides components of mixtures with differing magnetic properties.
- **Chromatography** separates substances based on solubility.
- **Centrifugation** can separate particles based on their densities.

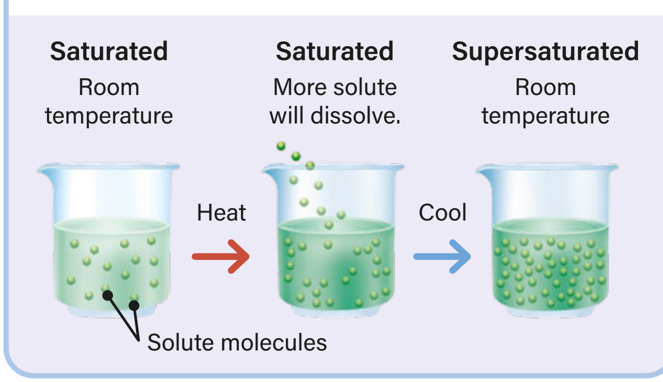
Concentration

Amount of solute present in a solution

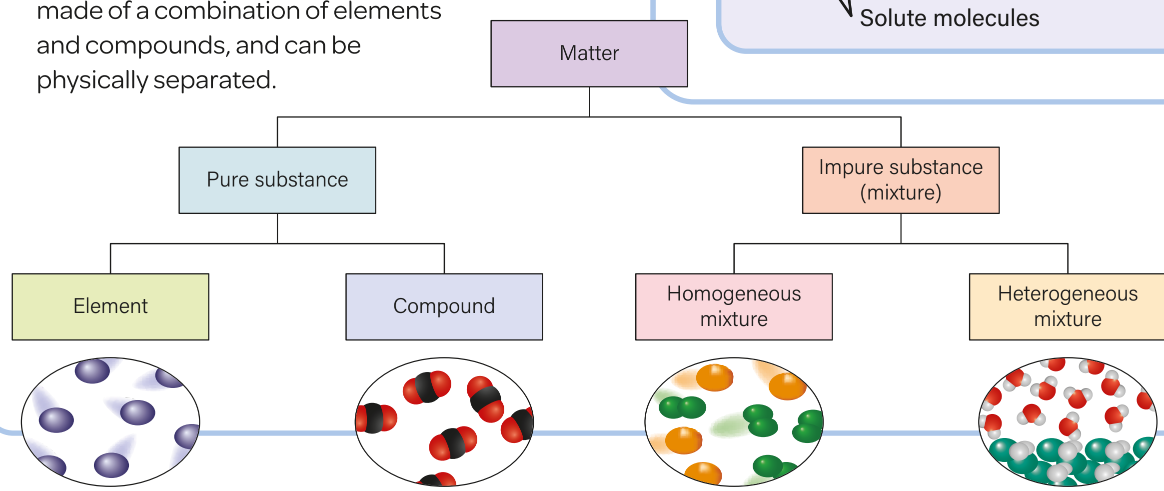


- A solution is made when one material (solute) is dissolved into a liquid such as water (solvent).
- Materials that cannot be dissolved are called insoluble.
- The higher the temperature of a solution, the more solute it can hold.
- Solutions can be dilute (contain low amounts of solute in a large volume) or concentrated (contain high amounts of solute in a smaller volume).
- Saturated solutions have dissolved the maximum possible amount of solute at a given temperature. Supersaturated solutions are heated and then slowly cooled, so the solution contains more solute than it could normally hold at room temperature.
- The concentration of solutions can be calculated using $c = \frac{m}{V}$.





- **Elements** are pure substances made of one type of atom.
- **Compounds** are pure substances containing atoms of two or more elements. The atoms are chemically bonded together and cannot be physically separated. Atoms are present in a compound in a fixed ratio.
- **Mixtures** are impure substances, made of a combination of elements and compounds, and can be physically separated.

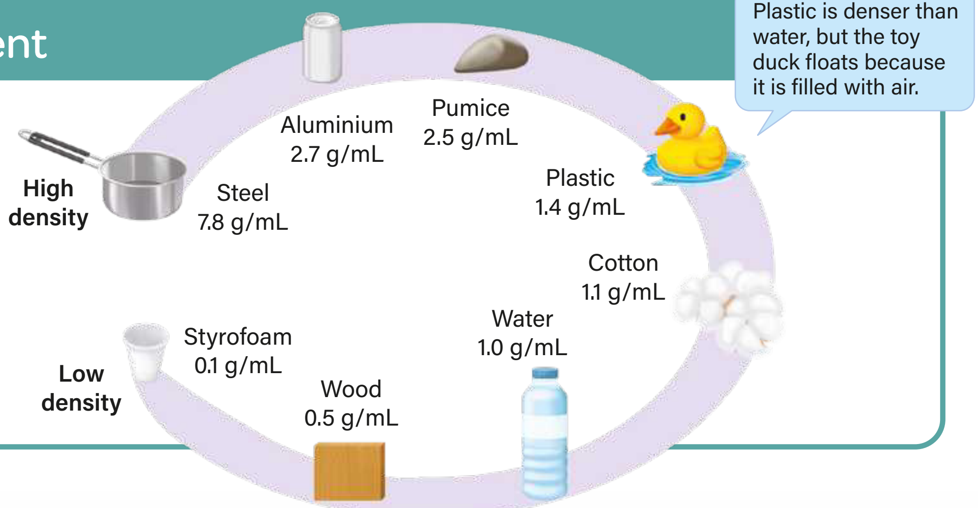


- Aboriginal and Torres Strait Islander Peoples use techniques such as winnowing, yandying and sieving to separate materials based on their sizes.
- Leaching can detoxify foods such as the cycad seed.

Industrial processes – such as purifying water for drinking – rely on separation techniques.

Key idea: Scale and measurement

- Density is the amount of matter in a certain volume.
- Density equals mass divided by volume.
- An object less dense than water will float; an object denser than water will sink.
- Density can be calculated by using the formula, $d = \frac{m}{V}$



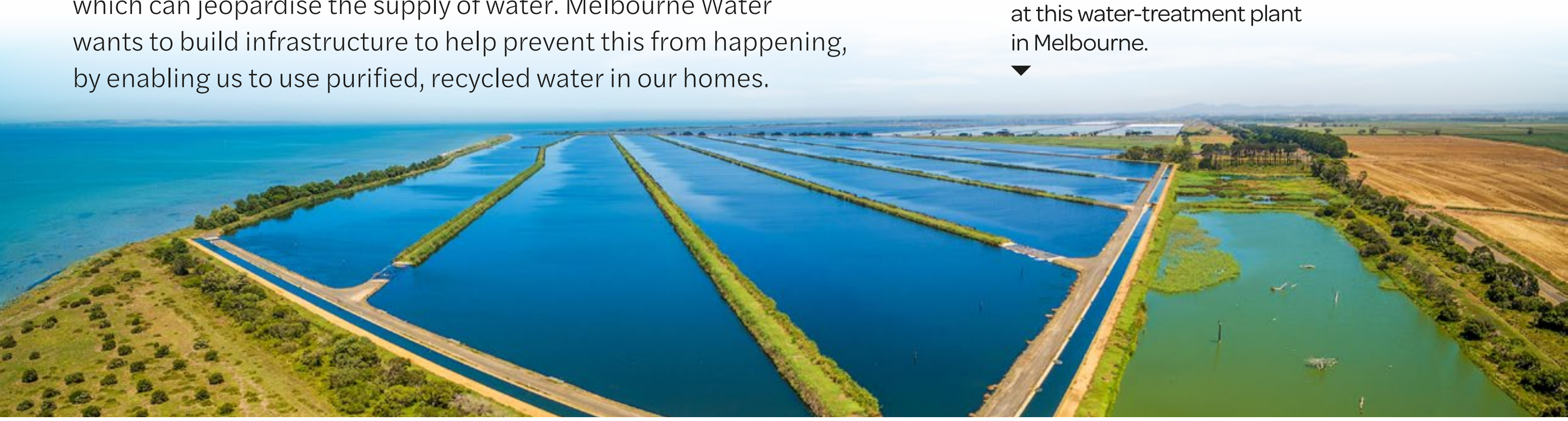
Masterclass

Steps in progression		1	2
Science understanding	Mixtures	Identify one chemical that is added to water when it is being treated to make it a safe solution.	**a** Describe a property of recycled water that is used in the purification process. **b** Name a technique used to purify water.
Science as a human endeavour	Nature and development of science	Propose a problem with water that can be solved using filtration treatment.	Describe the importance of collaboration among scientists from different backgrounds.
Science as a human endeavour	Use and influence of science	Propose a socio-scientific issue associated with untreated water and sewage.	Describe how multiple separation techniques can address scientific problems.
Science inquiry	Planning and conducting	Identify any familiar equipment being used in Figure 5.36 to test water samples.	Describe how you would minimise risk associated with the piece of equipment used in step 1.
Science inquiry	Processing, modelling and analysing	Identify measurements that can be recorded if you are collecting water samples.	Construct a flowchart to show how water can be purified using separation techniques.
Science inquiry	Evaluating	Identify a possible error shown in Figure 5.36 related to how the scientist is reading the instrument.	Describe two types of errors that can occur in purifying water.

Purifying water in Victoria takes recycling to the next level

The Australian climate means that Victoria experiences drought, which can jeopardise the supply of water. Melbourne Water wants to build infrastructure to help prevent this from happening, by enabling us to use purified, recycled water in our homes.

Figure 5.35: Exposing water to ultraviolet light helps to purify it, which is what is occurring at this water-treatment plant in Melbourne.



Demonstrate your understanding

3	4	5	
Explain how the process of ultrafiltration works when purifying a water sample.	Compare the properties of recycled water used in home showers and toilets to the properties of water collected from stormwater runoff.	Analyse the use of recycled water as an option to help protect Victoria's water supplies during drought.	
Explain the importance of chlorination as a technique for purifying water.	Discuss how water purification has evolved over time.	Analyse how different cultures perform water purification	
Explain the effects on society of new techniques such as desalination.	Discuss the impact of desalination plants on the environment.	South Australia uses a desalination plant to boost its water supply. Analyse the relevant government policy.	
A scientist wants to test the purity of a water sample that has been exposed to different chemicals. Identify: **a** the independent variable. **b** the dependent variable. **c** three controlled variables.	Explain how scientists who conduct tests on purified water ensure that the data they collect is accurate and precise.	Consider the test in step 3 and the collection techniques in step 4. Design a reproducible investigation and discuss any procedural and ethical considerations.	Science how-to p. 226
Sketch a graph showing the proposed relationship between water treated with different levels of chlorine.	Discuss the trends that could be observed with water being treated with and without chlorine.	Predict and analyse the relationship between chlorine level and bacterial growth.	Science how-to p. 230
Explain the link between issues with water purification processes and community health.	Drinking water must have a neutral acidity level. Propose and discuss the impact of acid rain on local water supplies.	Evaluate the success of ultraviolet light in Figure 5.35 and chlorine treatment in controlling bacterial levels, using evidence from Victoria's water resources.	Science how-to p. 239

This would mean that water used in our homes – even water from our showers and toilets – would be diverted to water-recovery facilities, then moved to special purification plants, before it is directed back into the dams that hold our water supplies. Recycled water would be treated using normal water-treatment processes, but would also undergo ultrafiltration. Ultrafiltration is when the water is passed through extremely fine filters, removing nearly all solids, including very small particles, as well as bacteria and viruses, making the water safer for consumption.

All water would still have the usual chemical components such as chlorine and fluoride added, so that it could be classed as being safe for consumption. The final water solution would be tested by scientists before being released back into water systems.

Figure 5.36: Scientists conduct quality control tests on water samples to ensure that our drinking water is safe.

6.0 Earth's resources

Earth provides all living things with everything they need to survive. Humans must use these resources carefully in order to limit our environmental impact and ensure there are enough resources for the future. Understanding how resources form, and in what timeframe, helps us to make sustainable decisions.

Learning Ladder

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

Steps in progression	Science understanding	Science as a human endeavour	
	Earth and space science: Earth's resources	**Nature and development of science**	**Use and influence of science**
5	I can evaluate processes of resource extraction and energy production	I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations
4	I can compare the benefits and risks of obtaining and using resources	I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues
3	I can explain the importance of using resources sustainably	I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances
2	I can distinguish between renewable and non-renewable resources	I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society
1	I can list Earth's resources	I can recognise scientific problems and solutions	I can identify socio-scientific issues

Figure 6.1: Wind farms use turbines to convert wind energy into electricity.

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

Science inquiry

6·1 ▸ 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

finite: limited in size or amount

fossil fuel: a natural fuel formed over millions of years from the remains of living things

infinite: never runs out

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

sustainable: supporting present needs without compromising the ability of future generations to support their needs

Investigation 6.1

Investigating classroom resources, p. 325

Key idea: Stability and change

A resource is anything that a person, or other living thing, uses in their everyday life. It can be vital to survival, such as food and water, or something that makes life easier, like metal and plastic. Some resources do not need to be changed much or at all before we can use them. Other resources are processed to become more useful.

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 timeframe.

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.

Resources can be natural or 'made'

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 (e.g. cotton and wood). But not every resource can be used without changing it. **Made resources** (like the plastics shown in Figure 6.5) are new materials manufactured from natural resources and are often very different from the original resource.

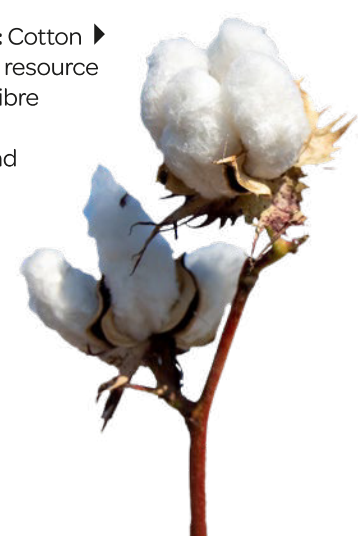


Figure 6.2: Cotton ▸ is a natural resource used as a fibre material in clothing and fabrics.

Figure 6.3: Tree trunks are a resource for timber.

Figure 6.4: Fruit and vegetables are important natural resources.

Figure 6.5: Plastic is a made resource used to manufacture a variety of products we use every day.

We need to use resources carefully

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. Taking and using resources can deplete or damage the natural environment. Therefore, 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
- the use of alternative resources to prevent damage to the environment.

Figure 6.6: Earth's resources need to be managed sustainably to protect the environment and ensure a high quality of life for present and future generations.

Learning Ladder

Earth's resources

1. List 10 resources you use in your daily life.
2. Describe the difference between renewable and non-renewable resources.
3. Explain why it is important to carefully manage how we use resources.
4. Compare a 'made resource' with a 'natural resource'.
5. Evaluate the logging of forests to produce wood and assess the sustainability of this practice.

Use and influence of science

1. Identify statements/questions from the list below that could be investigated scientifically.
   A Coal is the fossilised remains of plants.
   B All living things require resources to survive.
   C How old should a tree be before it is harvested for timber?
2. Describe how scientific knowledge about the formation of coal could help us understand how we should use this resource.

Communicating p. 245

1. Coal forms over millions of years. It is best described as a:
   A carbon resource. **B** made resource.
   C non-renewable resource. **D** renewable resource.
2. Write a list of all the different resources named or shown in this section. Construct a table, chart or diagram that allows you to classify them as renewable, non-renewable, made or natural.
3. Prepare a poster to present the information organised in Question 2.

Key idea: Stability and change

Compare the timeframes required for renewable and non-renewable resources to replenish.

Success criteria

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

6.2 ▸ Renewable resources

Learning intention

At the end of this lesson, I will be able to describe what a renewable resource is, using examples.

Key terms

bioplastics: plastics produced from plant materials, such as vegetable oils, starch and wood chips

solar energy: heat and light energy from the Sun

Investigation 6.2

Making bioplastic, p. 326

Key idea: Stability and change

We use renewable resources for food, materials and energy. Some renewable resources can replenish within a human life span, and some will never run out. Renewable resources can be from living things, such as plants and animals, and from non-living things, such as the Sun, wind and water.

The living parts of the world contain many different renewable resources, including plants and animals. Solar energy, wind and water are non-living renewable resources. We can use these and other resources for food, fuel and power.

Figure 6.7: Living things would not be able to survive without gases from the atmosphere. ▸

Living things are resources

Living things are important resources that provide us with food, materials and even energy. If we manage our use of them carefully, living resources can restore within a human life span.

Trees are grown and harvested to provide materials such as timber and paper. Other plants provide fruit and vegetable crops. Animals provide meat and materials such as wool, leather and honey.

Bioplastics are produced from plant materials such as vegetable oils, starch and wood chips. Bioplastics have properties similar to traditional plastics but with added advantages, including being biodegradable and being made from waste products left over from other processes.

Figure 6.8: Mountain ash forests are an important ecosystem in Victoria. They need to be managed sustainably.

The atmosphere is a resource

The atmosphere is the layer of gas that surrounds Earth. Life on our planet as we know it would not be able to survive without Earth's atmosphere. It is an infinite resource that provides living things with oxygen for respiration, and plants with carbon dioxide for photosynthesis and nitrogen to help them grow.

Gases in the atmosphere also protect Earth from harmful solar radiation and help to keep the surface of Earth at a constant temperature.

When air moves, it creates wind. Wind can be harnessed by windmills to pump water and by turbines to create electricity.

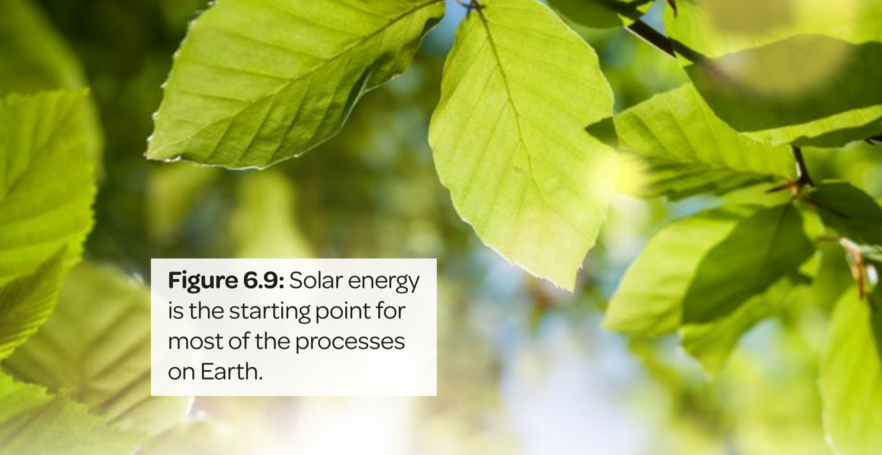


Figure 6.9: Solar energy is the starting point for most of the processes on Earth.

Water is a vital resource

All living things need water to survive. Water resources are sources of water that can be useful, such as rivers, lakes and dams. These resources can be used for drinking, for farming and by factories. All of the water on Earth cycles through the water cycle and can be considered a renewable resource. Around 97 per cent of the world's water is found in the oceans; however, most of the water that is used by humans is fresh (not salt water). These sources must be managed carefully to ensure they do not run out or become polluted.

The Sun is the source of most of the energy on Earth

The heat and light energy we get from the Sun is called **solar energy**. It is the starting point for most of the processes on Earth. Without the Sun's heat and light, nothing would live on Earth – our planet would be a cold rock.

Plants use the energy from the Sun for photosynthesis, which enables them to grow. This energy is then passed on to the organisms that eat the plants. The Sun's heat warms the air unevenly, causing air of different temperatures to meet and move as wind.

Solar energy can be harnessed to create electricity using solar panels or thermal systems.

Sustainable management of renewable resources

Although renewable resources may be infinite or may replenish within a human life span, they still need to be carefully managed to ensure they are able to be used now and in the future. Without careful management, the logging of forests could quickly destroy important ecosystems before they have time to recover. Overfishing can lead to the extinction of species and is prevented by the monitoring of populations and catch limits.

Learning Ladder

Earth's resources

1. Identify at least four different renewable resources listed in this section.
2. Copy and complete:
   - **a** Renewable resources can ____________ within a ____________ span, or are ____________ and will never run out.
   - **b** Renewable resources can be from living things, such as ______________, and ________________ such as the Sun, air and water.
3. Explain why it is important to manage freshwater resources.

Use and influence of science

1. Identify if the following statements are true or false. If they are false, rewrite them so they are true.
   - **a** Living things are useful non-renewable resources.
   - **b** The atmosphere provides living things with important gases.
   - **c** Around 97 per cent of Earth's water is fresh.
   - **d** Solar energy is the end point of most of the processes on Earth.
2. Describe how scientific knowledge about bioplastics could impact society.

Planning and conducting

p. 226

Read Investigation 6.2, 'Making bioplastic' (page 326), then answer the questions below.

1. Draw a labelled scientific diagram of the apparatus to be used in this investigation.
2. Identify three hazards present in this investigation. Describe how you will minimise the risk of each.
3. Identify the:
   - **a** independent variable.
   - **b** dependent variable.
   - **c** controlled variables.
4. Identify and describe the best way you could record precise data for this investigation.
5. Using the materials for this investigation as a basis, design an investigation that would allow you to test how the amount of cornflour, vinegar, glycerine or water would impact the bioplastic.

Key idea: Stability and change

Conduct some research to find out how your local water authority ensures that enough fresh water is available.

Success criteria

- I can describe what a renewable resource is.
- I can give examples of some renewable resources.

6.3 ▸ Non-renewable resources

Learning intention

At the end of this lesson, I will be able to describe what a non-renewable resource is, using examples.

Key terms

crude oil: oil that has not been separated into usable petroleum products

sediment: small particles of rocks, such as clay, sand and pebbles

Investigation 6.3

Investigating soil erosion, p. 327

Key idea: Stability and change

Non-renewable resources run out or are not replenished in a human life span. Rocks, minerals, fossil fuels and soil are some of the non-renewable resources we use that come from Earth's lithosphere (the solid, outer part of Earth). These resources are used to produce materials, generate energy and develop agriculture.

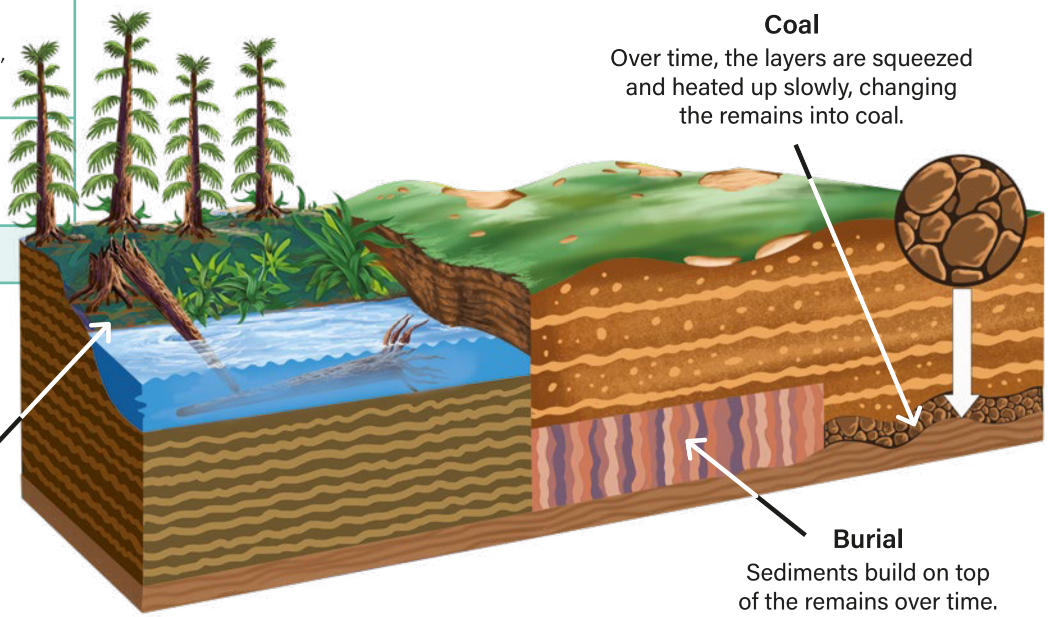


Figure 6.10: ▸ Coal is a non-renewable resource that forms from the remains of swamps over millions of years.

Fossil fuels include coal, oil and gas

Fossil fuels include coal, **crude oil** and natural gas. These resources are produced from the remains of ancient plants and animals, in processes that take hundreds of millions of years. While fossil fuels are still being formed today, they are being removed and used at a rate 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.

Oil and natural gas are formed from the remains of tiny marine organisms, such as algae and plankton, that die and sink to the bottom of the ocean. Conditions at the bottom of the ocean stop them from breaking down, so the remains build up in the **sediment**. This happens over millions of years. As the sediments are buried, heated and squashed, the remains undergo chemical reactions that produce oil and natural gas.

The use of fossil fuels creates large amounts of carbon dioxide which is released into the atmosphere, leading to climate change. The use of fossil fuels needs to be managed sustainably to reduce carbon dioxide emissions and to ensure these fuels are still available in the future.

Radioactive resources are rare and finite

Radioactive resources can be used to generate electricity, to power spacecraft and submarines, and to produce substances used in medicine.

Uranium is a common nuclear fuel that is mined in 19 countries, including Australia. Only very small quantities of uranium are needed to power a nuclear power plant, but uranium is still considered non-renewable because it is a finite resource – there is only a limited amount available on Earth.

Table 6.1: Common metals mined in Australia

Metal	Mineral ore(s)	Location	Most useful property	Material use
Iron	Haematite, magnetite	WA	Strong	Steel
Lithium	Spodumene	WA	Durable, resistant to temperature changes	Lithium-ion batteries
Aluminium	Bauxite	Qld, NT, WA	Lightweight	Drink cans, aircraft
Copper	Chalcopyrite	Qld, SA, NSW, WA	Good conductor of electricity	Electrical wiring, computers, coins
Zinc	Sphalerite	Qld, NSW, NT, Tas, WA	Resistant to corrosion, blocks UV rays	Galvanising steel, sunscreen

Rocks and minerals provide metals

Rocks and minerals are non-renewable resources because there are only limited amounts close to Earth's surface that humans can access. Rocks can be cut to create building stone or crushed to add strength to roads and concrete.

Rocks can contain minerals that hold useful metals such as aluminium, copper, lithium and iron. These minerals are known as metal ores, or mineral deposits when found in large amounts. Mining and extraction processes remove and purify metals from their ores for use in manufacturing many items.

Sustainable use of minerals includes recycling materials to ensure they are available in the future.

Soil takes hundreds of years to form

Soils are vital for plant growth and are important habitats for living things. They are a mixture of sediments, minerals, plant and animal material, air and water. A healthy soil is important for agriculture to produce crops, pasture for livestock, and forests. Soils are produced when rocks are weathered into sediment that is then mixed with the broken-down remains of dead plants and animals. One centimetre of soil can take hundreds, or even thousands, of years to form. Because soils take so long to form, they are considered a non-renewable resource.

Soil needs to be managed carefully on farms to ensure that the land can continue to be used to produce crops and support livestock into the future.

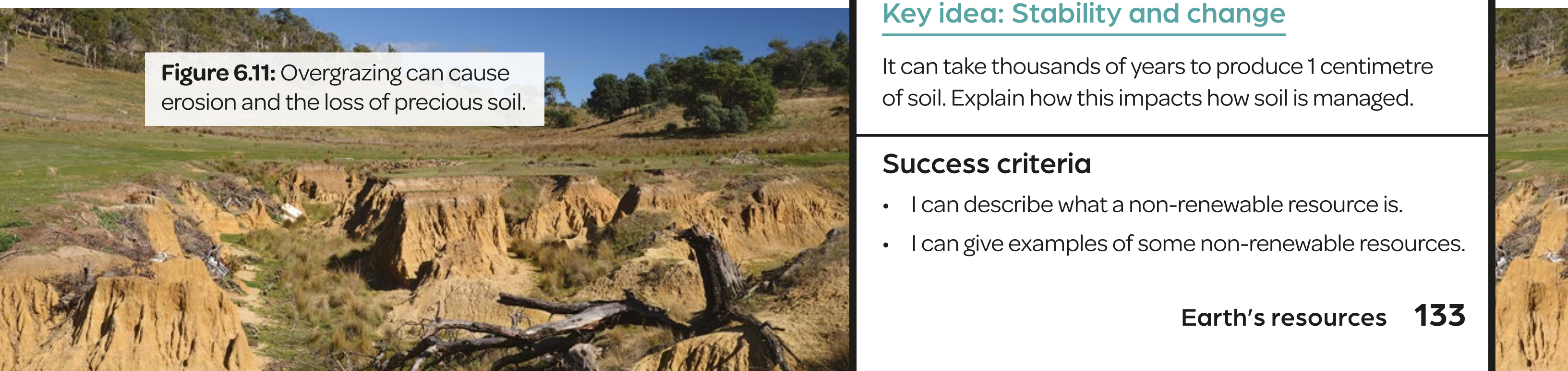


Figure 6.11: Overgrazing can cause erosion and the loss of precious soil.

Learning Ladder

Earth's resources

1. Identify at least four different non-renewable resources listed in this section.
2. Describe the key features that make resources non-renewable using examples.
3. Explain why minerals need to be managed sustainably.

Use and influence of science

1. Identify which of the three resources discussed is most important for your daily life.
2. Suggest how scientific knowledge on the formation of a resource could impact how it is managed.
3. Discuss why recycling is important for managing a non-renewable resource.

Evaluating *p. 239*

Read through Investigation 6.3, 'Investigating soil erosion', (p. 327) before completing Questions 1 and 2 below.

1. Identify a possible cause of error in the investigation.
2. For the answer you selected in Question 1, identify the type of error and describe its possible impact.

Answer the following questions about an investigation into overgrazing:

3. The investigation findings showed that smaller animals caused less erosion. Create an explanation to support this finding.
4. Justify the claim that soil with more plants and deeper root systems is less likely to erode.
5. The scientist concluded that land should be given time to recover after grazing. Evaluate this claim.

Key idea: Stability and change

It can take thousands of years to produce 1 centimetre of soil. Explain how this impacts how soil is managed.

Success criteria

- I can describe what a non-renewable resource is.
- I can give examples of some non-renewable resources.

6·4 ▸ Energy resources

Learning intention

At the end of this lesson, I will be able to describe some benefits and risks of renewable and non-renewable energy resources.

Key term

hydropower: electricity generated by flowing water turning a turbine

Investigation 6.4

Designing a windmill to lift a weight, p. 328

Key idea: Stability and change

You wake up in the morning and switch on a light, take a hot shower and use kitchen appliances to make your breakfast. You leave your house in a car, or perhaps you catch a bus or a tram. All of these activities rely on energy. Traditionally, much of Australia's energy has been produced by fossil fuels. In recent years, however, more and more of Australia's energy has been produced from renewable sources.

Fossil fuels are burnt to create energy

Fossil fuels are often burnt to provide heat energy. In power plants, this heat energy is used to change water into steam, which then spins large, fan-like machines called turbines.

The use of fossil fuels creates large amounts of carbon dioxide. When this gas is released into the environment, it causes air pollution and climate change.

In cars that have an internal combustion engine, the fuel is burnt in air. This causes energy to be released, which is then harnessed to turn the wheels.

Figure 6.12: The Yallourn Power Station is one of three coal-fired power stations still operating in Victoria's Latrobe Valley. The stations burn coal from nearby mines to produce electricity.

Sunlight can be used to create electricity

As long as the Sun continues to burn, it will create energy. We can harness this energy to create electricity. Solar panels create an electrical current when sunlight hits their surface. This electricity can then be used to power homes and appliances, be stored in a battery or be added to the electricity grid. Solar thermal systems use sunlight to heat water or air in buildings, as well as to heat the water in backyard swimming pools. Large solar thermal systems heat the water to create steam, which can then be used to turn a turbine, creating electricity.

Figure 6.13: Energy from the Sun is converted into electricity using solar panels. The Victorian government's Solar Victoria programs encourage people to use solar power in their homes by offering financial help with the cost of installing rooftop solar panels.

Figure 6.14: Winneke Solar Farm uses 19 000 solar panels to generate power for the Winneke Water Treatment Plant, north-east of Melbourne. Each year, the farm generates enough electricity to power 2500 homes!

Figure 6.15: Dams throughout the Snowy Mountains are used to generate hydroelectricity. The movement of falling water is used to spin turbines.

Flowing water can generate power

Hydropower, the energy from moving water, such as waves or in dams, can be harnessed to create electricity. In the same way that wind power uses moving air to turn a turbine, hydropower uses water. The falling or flowing water turns the turbine, which then generates electricity.

Nuclear energy

Uranium is the most common nuclear fuel used in nuclear power stations. These operate similarly to coal power stations in that they produce heat that turns a turbine to generate electricity.

There are no nuclear power stations in Australia. The use of nuclear power is a controversial issue. It is a very expensive technology, and if something does go wrong, the effects can be long-lasting and extremely dangerous.

Wind power is a renewable resource

You have probably seen a turbine or even a whole wind farm before, in Australia or overseas. Denmark uses the most wind power – in 2020, about 56 per cent of its power was generated from wind farms.

To create electricity, turbine blades are moved by the wind, and the rotation of the blades powers a generator (similar to coal and hydropower generation). The costs of wind power are fairly low, but wind does have some disadvantages. For example, the electricity supply is not constant because if there is no wind, then no power can be generated!

Figure 6.16: Wind energy is converted into electricity when wind turns the turbines. Lal Lal Wind Farm is one of the largest wind farms in Victoria, with more than 60 turbines.

Sustainable energy

Burning of fossil fuels to create energy is not a sustainable practice. Fossil fuels are a finite resource, but more important is the impact the carbon dioxide emissions are having on Earth's atmosphere and climate. To address this issue, a lot of research has been done to develop technologies that create and use renewable energy. For example, batteries are being used to store excess solar energy so that it can be used overnight. Pumped hydro uses excess renewable energy to pump water uphill into dams that can then be released to turn turbines when renewable energy is low. And electric cars create significantly less emissions compared to petrol-powered cars, especially if they are charged using renewable energy.

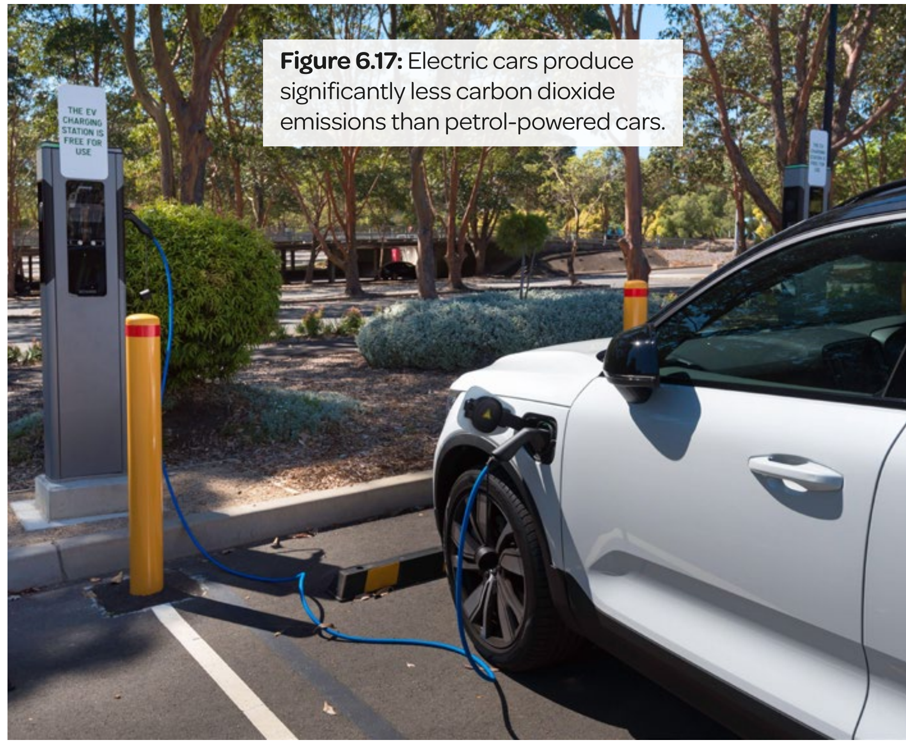


Figure 6.17: Electric cars produce significantly less carbon dioxide emissions than petrol-powered cars.

Learning Ladder

Earth's resources

1. List the energy resources discussed in this section.
2. Classify the resources you listed in Question 1 as renewable or non-renewable.
3. Explain one reason why it is important to use renewable sources of energy.

Use and influence of science

1. Identify if the statements below are true or false. If they are false, rewrite them so that they are true.
   - **a** New energy technologies can be more expensive than older ones.
   - **b** The burning of fossil fuels causes climate change.
   - **c** The burning of fossil fuels is sustainable.
   - **d** Solar panels convert sunlight into electricity by turning turbines.
2. Describe some technologies that have been developed to help reduce the use of fossil fuels to produce energy.
3. Hydroelectric schemes store water in dams that is used to spin big turbines to generate electricity. Explain at least one impact these schemes can have on the environment.
4. Some communities do not want wind farms in their local area. However, some farmers might be paid money in exchange for agreeing to build wind turbines on their land. Discuss how this way of dealing with the issue might impact the community.
5. Analyse how communicating scientific knowledge of renewable energy might help make wind farms more acceptable to a community.

Communicating p. 245

1. Write a definition for:
   - **a** renewable energy.
   - **b** non-renewable energy.
2. Brainstorm ideas for the best way to communicate the difference between renewable and non-renewable energy to Year 4 students.
3. Undertake further research to create a poster or an infographic to illustrate the benefits and risks of different forms of energy production.

Key idea: Stability and change

Choose one of the following car technologies. Undertake some research to compare its benefits with the benefits of a traditional petrol-powered car.

A Hybrid
B Electric
C Hydrogen-powered
D Solar-powered

Success criteria

- I can describe some benefits and risks from renewable and non-renewable energy resources.

6.5 ▸ Mining Australian mineral resources

Learning intention

At the end of this lesson, I will be able to describe the mining process and some examples of metals that are mined in Australia.

Key terms

exploration: processes undertaken to find rocks that contain minerals

mineral deposit: rocks that contain a particular mineral

ore body: a mineral deposit that is profitable to mine

rehabilitation: processes that return the environment to close to how it was before mining

Investigation 6.5

Mining for chocolate chips, p. 329

Key idea: Stability and change

Mining allows us to access resources from Earth that we use in our everyday lives. The process of locating, removing and processing a resource requires expertise from scientists in many different areas to minimise the impacts mining will have on the natural environment.

Locating the resource

To meet the demand for resources, mining companies conduct **explorations** to find areas that have high concentrations of the **mineral deposits** that contain the resource they want to mine. If they are granted permission from the government and landholders to explore in a particular area, they may use different exploration techniques to find these deposits.

Extracting the ore

An **ore body** is a mineral deposit that is profitable to mine. After an ore body has been located, mining companies need to work out the most cost-effective, safe and environmentally friendly way of removing the ore from the surrounding rock. This could mean scraping off the surface layer to form an open-cut mine or digging shafts deep down into the rock to create an underground mine. If costs will be too high, the company will not construct the mine and will continue to explore.

Figure 6.18: The stages of mining include exploration and evaluation, construction of the mine, extraction of the ore and rehabilitation of the mine site.

EXPLORATION
5–10 YEARS
INVESTMENT OF $1–5 million
Gathering data about potential mineral deposits and acquiring the rights to harvest those deposits.

EVALUATION
5 YEARS
INVESTMENT OF $0.5–100 million
Geological, technical and environmental analyses, plus community input. Financing and government-approved closure plan must be secured.

CONSTRUCTION AND EARLY PRODUCTION
5–10 YEARS
INVESTMENT OF $750–1500 million
Building of roads, environmental management systems, employee housing, processing and other facilties after investments, permits and approvals are obtained.

COMMERCIAL PRODUCTION
10–20 YEARS
Production of minerals and metals that make modern life a reality, supplying downstream processing and boosting sectors across the economy. Exploration often continues, adding to existing reserves.

CLOSURE AND RECLAMATION
2 YEARS INTO PERPETUITY
INVESTMENT OF $1–500 million
Mining operations are decommissioned responsibly and the land is returned to a natural or economically usable state.

Extracting the metal

After ore has been removed, it needs to be processed to extract (take out) the resource it contains. The main processes involve crushing the ore and using chemical reactions to separate the resource from the other elements in the mineral.

Metallurgical engineers specialise in extracting metals from ore. They analyse the ore mineral and determine the most effective way to extract the metal. They monitor the extraction process to make sure that it is efficient and safe for the environment.

Rehabilitation

At all times throughout the mining process, a mining company must take care to protect the natural environment. Before mining can begin, a plan needs to be put in place that shows how the site will be rehabilitated at the end of the mining process. When mining is finished, any land that has been impacted by the mine must undergo **rehabilitation** to return it to the way it was before the mining began. This is to ensure that no damage is done, biodiversity is maintained and the site is safe.

Australian metal resources

Iron ore is a vital mineral resource in Australia. 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.

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.

Learning Ladder

Earth's resources

1. List three of the major metals mined in Australia.
2. Is aluminium a renewable or non-renewable resource? Justify your response.
3. Explain the importance of using lithium resources sustainably.
4. Compare the benefits and risks of obtaining and using aluminium.
5. Evaluate the statement: 'Australia's mining industry must not be limited, as it provides access to critical mineral resources.'

Use and influence of science

1. Propose a problem that would need to be solved if there were no lithium deposits in Australia.
2. Describe how improvements in extracting metals from ore would contribute to the sustainable use of the ore body.
3. Explain the impact that mining would have on the environment if sites were not rehabilitated after the ore is extracted.

Evaluating

p. 239

Read through Investigation 6.5, 'Mining for chocolate chips', (p. 329) before answering the following questions.

1. From the list below, identify which actions would be more likely to cause an error in this investigation.
   - **A** Forgetting to set the scale to zero after adding the cupcake liner for every biscuit.
   - **B** Having an electronic balance that added an extra 5 grams to every measurement.
   - **C** Leaving cookie crumbs around the chocolate chips from one brand of cookie but not the others.
   - **D** Repeating the investigation using multiple cookies from each brand.
2. For the answer you selected in Question 1, identify the type of error and describe the impact it could have on the final results.

Key idea: Stability and change

Conduct research to present a case study of the steps taken to rehabilitate an old mine site. Suggested mines include: Ensham Coal Mine (Qld); Fosterville Gold Mine (Vic); Peak Hill Gold Mine (NSW); Rhondda Colliery (NSW).

Success criteria

- I can describe the main steps in the mining process.
- I can identify some metals that are mined in Australia and their uses.

6·6 ▸ The impacts of extracting resources

Learning intention

At the end of this lesson, I will be able to recognise some impacts of extracting and using Australian resources and describe different points of view.

Key terms

biodiversity: the variety of organisms in an ecosystem

habitat: The place where an animal or a plant naturally lives

Key idea: Stability and change

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.

Figure 6.19: The mining industry creates tens of thousands of jobs, from chemical engineers to architects, civil workers and drone pilots.

Figure 6.20: Scientists analyse waste water to consider the best approach for land rehabilitation.

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. The logging of a forest can destroy important ecosystems, and overfishing can lead to the extinction of species. 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. Catch limits are put in place to prevent overfishing, and legislation limits the area of native forest that can be logged. 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.

Making choices involves considering 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 6.2).

Table 6.2: 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

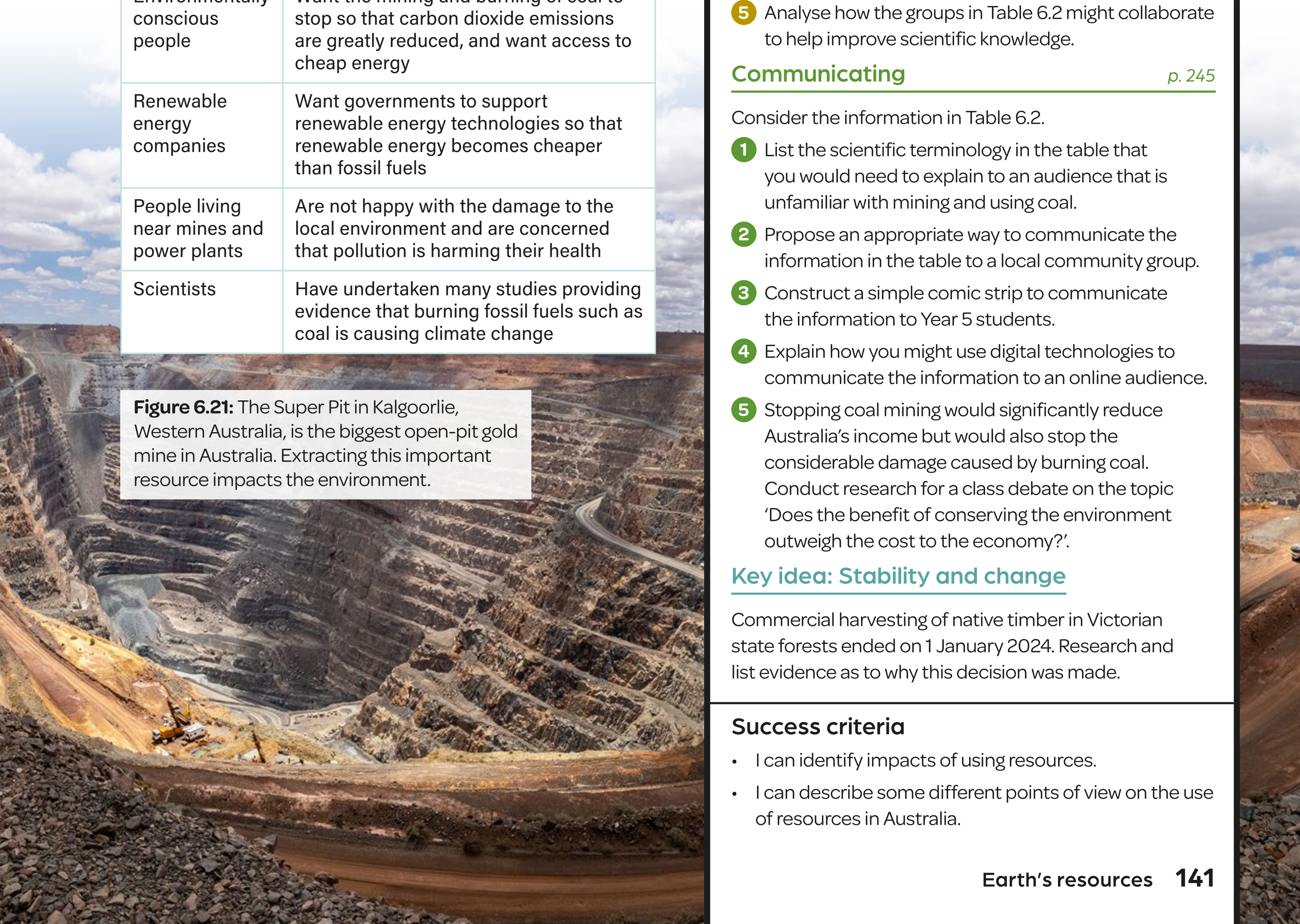


Figure 6.21: The Super Pit in Kalgoorlie, Western Australia, is the biggest open-pit gold mine in Australia. Extracting this important resource impacts the environment.

Learning Ladder

Earth's resources

1. List at least five different resources that we obtain and use in Australia.
2. Identify whether the resources from your list above are renewable or non-renewable.
3. Explain the importance of understanding how the natural environment can be affected by obtaining or using resources.
4. Use Table 6.2 to compare the benefits and risks of mining and using coal.

Nature and development of science

1. Identify a scientific problem with extracting resources.
2. Using Table 6.2, describe why it is important for different scientists to collaborate.
3. Explain how new evidence might have deepened our understanding of the impacts of extracting resources.
4. Coal was once accepted as a main fuel source. Discuss how theories have changed over time to make coal use less acceptable.
5. Analyse how the groups in Table 6.2 might collaborate to help improve scientific knowledge.

Communicating

p. 245

Consider the information in Table 6.2.

1. List the scientific terminology in the table that you would need to explain to an audience that is unfamiliar with mining and using coal.
2. Propose an appropriate way to communicate the information in the table to a local community group.
3. Construct a simple comic strip to communicate the information to Year 5 students.
4. Explain how you might use digital technologies to communicate the information to an online audience.
5. Stopping coal mining would significantly reduce Australia's income but would also stop the considerable damage caused by burning coal. Conduct research for a class debate on the topic 'Does the benefit of conserving the environment outweigh the cost to the economy?'.

Key idea: Stability and change

Commercial harvesting of native timber in Victorian state forests ended on 1 January 2024. Research and list evidence as to why this decision was made.

Success criteria

- I can identify impacts of using resources.
- I can describe some different points of view on the use of resources in Australia.

6.7 ▸ Using resources sustainably

Learning intention

At the end of this lesson, I will be able to discuss some strategies that will reduce and improve our use of resources.

Key terms

landfill: disposal of waste by burying it

recycling: converting waste into reusable materials

Key idea: Stability and change

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, the average household throws out more than 3.3 tonnes of food – the equivalent of 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 1.8 billion single-use coffee cups are used each year in Australia, with most of them going into landfill. By changing our buying habits, we can not only reduce the amount of resources we use and the amount of non-recyclable waste we produce, but also reduce the use of resources that are consumed in the manufacture of these items.

▲ **Figure 6.22:** More than 1.8 billion single-use coffee cups are used in Australia every year.

▲ **Figure 6.23:** Repairing items can allow them to be reused.

Figure 6.24: 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 6.25: 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

Earth's resources

1. Identify some resources that can be easily:
   a reduced. **b** reused. **c** recycled.
2. Describe the difference in the impact between recycling a renewable and a non-renewable resource.
3. Paper is made from fibres obtained from trees. Discuss the effect that paper recycling has on the management of this natural resource.
4. Discuss the benefits of using tyres as an alternative to coal in the steel-making process.
5. 'Reduce, reuse and recycle' is a common catchphrase. Evaluate which strategy is most effective in the sustainable management of resources.

Use and influence of science

1. Propose a resource that you could easily reduce your use of.
2. Describe the difference between reusing and recycling an item.
3. Explain how using carbon from coal to make steel would have influenced research into finding alternative sources of carbon.

Planning and conducting

p. 226

Conduct research to find out how you can make handmade paper and design a scientific investigation.

1. Identify the equipment you will need for your investigation.
2. Identify any risks or hazards involved and describe how you will minimise them.
3. For your investigation identify the:
   a independent variable. **b** dependent variable.
   c controlled variables.
4. Describe the data you would gather including what instruments or tools you will use.
5. Use steps 1–4 to help you design and conduct your investigation, including writing a full scientific report. For help, see the Science how-to on p. 250.

Key idea: Stability and change

'Sustainability is the responsibility of every individual, every day.' Evaluate this statement by using evidence.

Success criteria

- I can discuss some strategies that reduce our use of resources.
- I can discuss some strategies that improve our use of resources.

6·8 ▸ Key idea: Stability and change – resource use and the environment

Learning intention

At the end of this lesson, I will be able to discuss how different campaigns have influenced communities to change how they use resources and manage waste.

Key idea: Stability and change

Single-use plastics are not a sustainable option. They can only be made from a non-renewable resource, and they contribute significantly to landfill and environmental pollution. Many individuals and groups across Australia are leading their community to change how we use these items.

Figure 6.26: Many different campaigns have helped to show the community the impact of unsustainable use of resources.

Figure 6.27: Single-use plastic shopping bags are a large source of plastic pollution.

Figure 6.28: Recycled paper shopping bags have replaced plastic bags at supermarkets. They can be reused, or recycled in household paper recycling bins.

Advocating for change: saying 'nup' to the single-use cup

Australians use more than 1.8 billion single-use coffee cups every year, with most of them going to landfill. Even though single-use coffee cups may seem like they are made of paper, many are lined with plastic that recycling plants cannot process. In recent years, there have been many campaigns to get people to use reusable cups instead. These campaigns have included the production of documentary films, as well as efforts in local communities, to educate people about how many coffee cups end up in landfill. These campaigns have resulted in people changing how they get their coffee. Many Australians now use a reusable takeaway coffee cup; Western Australia has passed laws to ensure that single-use coffee cups used in that state are made from compostable material; and in December 2024 the NSW town of Bermagui became the first community in Australia to completely ban single-use coffee cups. Making these changes has not been an easy process. People need to remember to have their reusable cup with them, many cafes returned to using disposable options during the COVID-19 pandemic, and governments need to build more industrial composting facilities to process compostable options.

No more plastic shopping bags

Many organisations, such as Clean Up Australia and Greenpeace, have led campaigns to ban the use of single-use plastic shopping bags. In 2003, the small town of Coles Bay in Tasmania was the first place in Australia to ban their use. Since then, all states and territories have imposed bans, with New South Wales being the last state to implement a ban in June 2022. This ban, and the change to people using paper or fabric bags, has resulted in a reduction of the amount of plastic pollution in the environment.

Recycling is easy

In the 1980s and 1990s, many Australian councils introduced kerbside recycling pick-ups. This initiative made it much easier for households to recycle items made of paper, cardboard, metal and plastic.

In the 2020s, household recycling is available in most parts of Australia. However, each council has its own rules on what can be recycled, depending on where the waste is processed, so sometimes it can be confusing to know if your pizza box or plastic bottle can be recycled. Contamination by items that are not recyclable can lead to many loads of waste being sent to landfill instead of being recycled. Many councils run education programs that teach people what items and materials can be put into the yellow bins for recycling. Container deposit schemes pay people to return their drink containers to be recycled. The introduction of these schemes has reduced the amount of waste that ends up in landfill and pollutes the environment.

Figure 6.29: Household recycling is available in most parts of Australia. Local councils provide colour-coded bins to help people separate their rubbish and items for recycling.

Learning Ladder

Earth's resources

1. List some examples of single-use plastics.
2. Describe the impact the following can have on the environment:
   - **a** single-use coffee cups.
   - **b** single-use plastic bags.
   - **c** all waste going to landfill.

Use and influence of science

1. Copy and complete:
   Australians use more than a ______________ single-use ______________ every year, with ______________ of them going to ______________.
2. Describe how scientific knowledge about the impact of plastic pollution has led to change in the use of single-use plastics.
3. Explain how a community focus on the sustainable use of resources led to the development of technologies such as compostable packaging.

Planning and conducting

p. 226

A waste audit can be undertaken to identify the type of waste a household, school or community is producing and help to determine ways to improve resource use and how waste is managed. Imagine that your class is going to conduct a waste audit at your school.

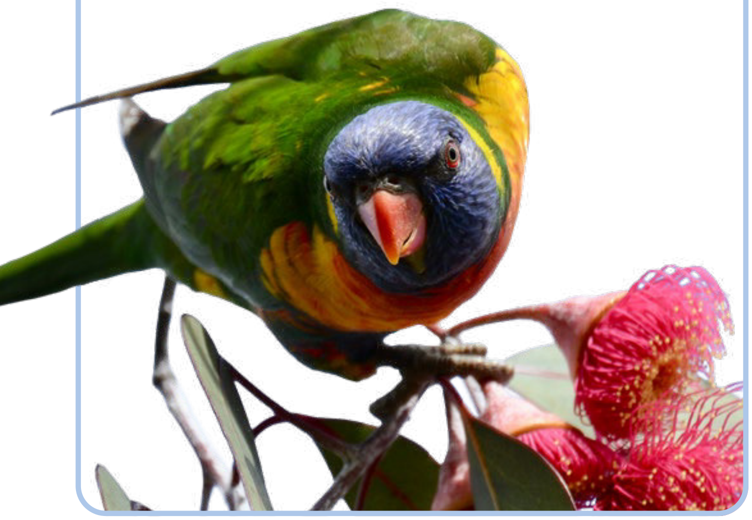
1. Identify equipment you would need to conduct the waste audit.
2. **a** Identify risks and hazards in conducting the audit.
   b Describe what equipment and techniques you will use to mitigate the risks and hazards.
3. You want to investigate if there is a difference in how people use the recycling bins in different year group areas of your school. Identify the:
   - **a** independent variable.
   - **b** dependent variable.
   - **c** controlled variables.
4. Use your answers to Question 3 to help you describe the data that you would collect to support the statement: 'The waste in the Year 7 recycling bins is the least contaminated.'
5. Use your answers to the questions above to write a report about conducting a waste audit at your school or home. Include an aim, materials list, method and a results table. If you are able to, complete the waste audit, results, discussion and conclusion of the report.

Success criteria

- I can discuss how campaigns have influenced communities to change how they use resources and manage waste.

Summary

A resource is anything that a person, or other living thing, uses in their everyday life.



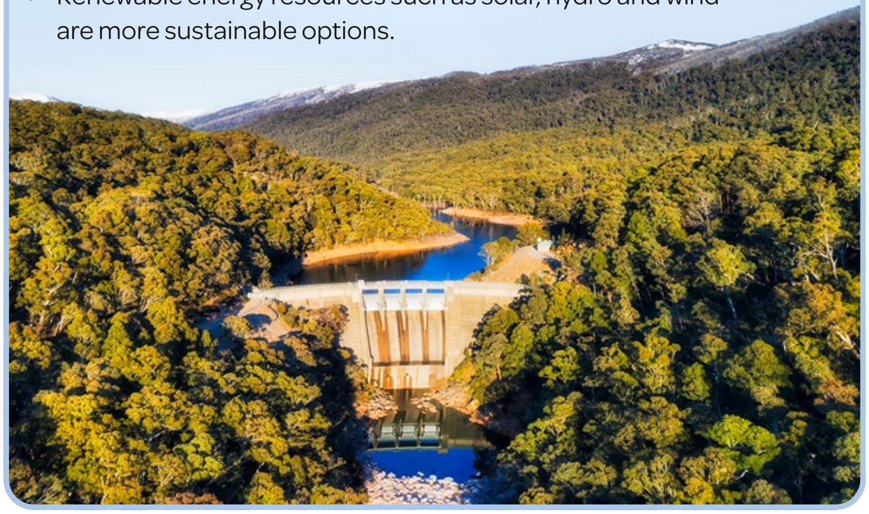
- A renewable resource can replenish in a human life span or is infinite.
- A non-renewable resource takes longer than a human life span to replenish or is finite.

Renewable resource	Non-renewable resource
Plants	Fossil fuels
Animals	Soil
Wind	Rocks and minerals
Solar energy	

Sustainable resource use can include:

- careful monitoring of natural resources such as fish populations and forests to prevent overharvesting
- reducing use of, reusing and recycling materials
- using alternative resources to prevent damage to the environment.

- Energy can be created from renewable or non-renewable resources. The burning of fossil fuels is not sustainable as the resource is finite and burning it pollutes Earth's atmosphere.
- Renewable energy resources such as solar, hydro and wind are more sustainable options.



Metals such as aluminium, copper, iron and lithium are obtained through the mining process.

We must consider the environmental and social impacts of extracting and using resources.

Key idea: Stability and change

Individuals and communities have successfully campaigned for the more sustainable use of resources, including banning single-use plastic bags and coffee cups.

Masterclass

Steps in progression

		1	2
Science understanding	**Earth's resources**	Aluminium is a metal. List some other resources that are metals.	Identify if aluminium is a renewable or non-renewable resource. Explain your choice.
Science as a human endeavour	**Nature and development of science**	Aluminium is a very useful material, but this resource will eventually run out. Identify the most effective solution to this problem. **A** Reduce **B** Reuse **C** Recycle	Suggest how different disciplines of science could collaborate to improve the recycling process.
Science as a human endeavour	**Use and influence of science**	Identify a reason why people may not recycle their aluminium cans.	Describe how scientific knowledge of sustainability has changed how we use resources.
Science inquiry	**Planning and conducting** Imagine you want to investigate and compare the number of aluminium cans that are put in waste and recycling bins at your school.	List the equipment you would need in order to undertake the investigation.	Think about how you would undertake this investigation. Describe how you would minimise any risks.
Science inquiry	**Evaluating**	Review your method. Are there any sources of error?	Some aluminium cans still have liquid in them. Describe what type of error this could lead to if you are measuring the amount of aluminium by mass.
Science inquiry	**Communicating** Imagine you are designing a campaign to decrease the number of aluminium cans that end up in landfill at your school.	List the key scientific terms you will need to use to communicate your message.	Brainstorm different ways you can communicate your message.

Figure 6.30: Aluminium is a versatile resource that is easily recyclable.

Recycling aluminium

Aluminium is 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 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 off the coating. It is then melted down in a furnace. The molten aluminium is cast into bricks called ingots for reuse.

Demonstrate your understanding

3	4	5	
Explain the importance of using aluminium sustainably.	Compare the risks and benefits of obtaining and using aluminium. *Hint:* See Sections 6.5 and 6.6.	Aluminium is easily recycled. Evaluate the need for mining and extracting more aluminium.	
Explain how new scientific evidence would have contributed to the development of recycling programs.	Household recycling only became common in Australia in the 1980s and 1990s. Discuss how attitudes to recycling have changed since then.	Analyse the importance of community collaboration when developing recycling campaigns.	
Explain how the need to use resources like aluminium sustainably has provided opportunities for the development of new technologies.	Discuss the impact that aluminium recycling programs have on the community and the environment.	Evaluate the impact of campaigns, such as the introduction of container deposit schemes, on increasing aluminium recycling.	
For this investigation, identify the variables that would be: **a** independent (changed). **b** dependent (measured). **c** controlled (kept the same).	Design a results table to record your data.	Use your answers to Questions 1–4 to help you write an aim, materials list and method for your investigation.	Science how-to p. 226
You find that 50 per cent of aluminium cans are put in the waste bins. Brainstorm some ideas to suggest why this is not zero.	Use scientific evidence to explain why your school should aim to bring the number of cans in the waste bins to zero.	'It is too hard to go to the recycling bin.' Write a statement that uses scientific evidence to change this attitude.	Science how-to p. 239
Select one of your ideas from Question 2 and create a draft version.	Outline how you could use digital technologies to communicate your message to your school community.	Write some talking points that you could use during your campaign. Ensure you use scientific evidence.	Science how-to p. 245

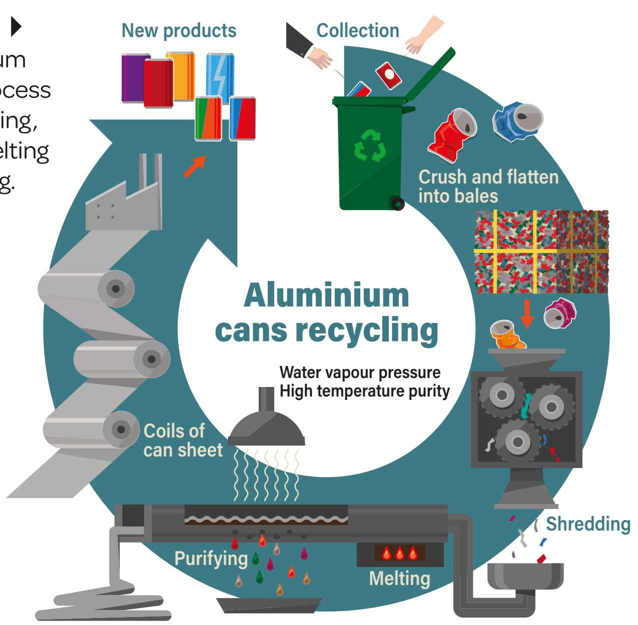


Figure 6.31: The aluminium recycling process involves sorting, crushing, melting and recasting.

Figure 6.32: Aluminium is melted down in furnaces as part of the recycling process.

7.0 Earth, the Sun and the Moon

Many ancient cultures thought that Earth was at the centre of the universe. They believed this because the Sun and other planets seemed to move in a cyclical way in Earth's sky, causing night and day and other predictable phenomena.

We now know that Earth revolves around the Sun. The Sun is the largest body in our solar system, with the largest gravitational pull. For the same reason, our Moon revolves around Earth. We also understand that the tilt of Earth's axis causes the seasons; and that the relative position of the Sun, the Moon and Earth cause phenomena such as eclipses, tides and the phases of the Moon.

Learning Ladder

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

Steps in progression	Science understanding: Earth and space science: Earth, the Sun and the Moon	Science as a human endeavour: Nature and development of science	Science as a human endeavour: Use and influence of science
5	I can analyse scenarios where celestial phenomena impact society	I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations
4	I can compare and contrast historical and contemporary understandings of celestial phenomena	I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues
3	I can model the Earth–Sun–Moon cyclic changes to explain the observable changes on Earth	I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances
2	I can describe observable changes on Earth caused by celestial bodies	I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society
1	I can identify the key features of our solar system	I can recognise scientific problems and solutions	I can identify socio-scientific issues

Figure 7.1: The tilt and position of Earth relative to the Sun and Moon cause events such as tides, eclipses and moon phases.

Questioning and predicting	Processing, modelling and analysing	Evaluating	Steps in progression
I can evaluate investigation questions and predictions for scientific validity	I can analyse processed data for patterns, trends, relationships and anomalies	I can evaluate conclusions and claims with reference to conflicting evidence and unanswered questions	5
I can develop a hypothesis that predicts the relationship between investigation variables	I can identify and discuss trends and/or patterns in a range of dataset representations	I can create evidence-based arguments to justify conclusions or evaluate claims	4
I can construct questions and predictions to investigate scientific problems	I can process data by using mathematical relationships and/or constructing graphs	I can use science-based explanations to support investigation findings	3
I can make simple predictions based on what I know and observe	I can organise and display data using tables, keys and/or models	I can describe different types of errors in an investigation method	2
I can recognise questions that can be investigated scientifically	I can identify data from tables and graphs	I can identify errors and assumptions in an investigation	1

Science inquiry

7·1 ▸ Observing the night sky

Learning intention

At the end of this lesson, I will be able to identify key features of our solar system and describe how cyclical changes in the relative positions of Earth, the Sun and the Moon cause predictable phenomena on Earth, including night and day.

Key terms

axis: a real or imaginary line through the centre of an object

galaxy: a large system of stars

orbit: the path of an object around a star or planet; for example, Earth around the Sun, or the Moon around Earth

pendulum: a mass that is attached to a fixed point by a string and can move backwards and forwards freely

revolve: move in a circular path around another object

rotate: spin on an axis

Investigation 7.1

Modelling day and night, p. 330

Key idea: Systems

People have been fascinated by the night sky since the very beginning of human life on Earth. The movements of the Sun, Moon, stars and planets played an important role in many ancient cultures. Ancient peoples made detailed observations and created models to try to make sense of the world around them and the position of Earth in relation to the rest of the observable universe.

Ancient astronomers

Early astronomers made their observations of the night sky with the naked eye. They recorded the movements of celestial bodies in oral traditions, writing and art, and even by creating arrangements of giant stones. They recognised regular patterns, such as the movements of the Sun across the daytime sky from east to west, and of the Moon across the sky each night along with its changing shape during each month.

Australia's First Nations Peoples distinguished the planets from the background of stars. They observed how their positions in the sky, and in relation to each other, changed over the course of days, months and years. They knew that sometimes they move close together, and sometimes they appear to change speed and move backwards (retrograde motion). In many traditions, the planets represent ancestor spirits walking across the sky, connecting various groups of stars.

Our place in space

The Sun is a star at the centre of our solar system. It is an enormous, dense ball of gas that produces light and heat. The nuclear reactions inside the core of the Sun are so powerful, the energy produced can light and heat Earth. Light from the Sun takes about eight minutes to reach Earth.

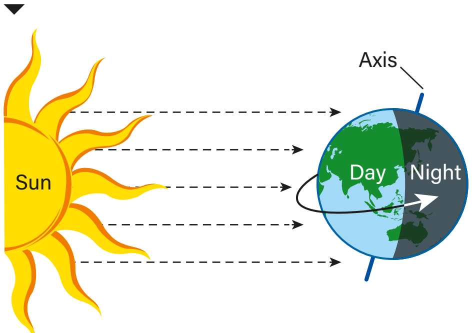
Earth is one of eight planets that **revolve** around the Sun. Earth's orbit is roughly the shape of a squashed circle, and each revolution takes one year (365 days).

We know that our solar system is one of billions within the Milky Way **galaxy**. In turn, our galaxy is just one of billions in the universe.

Day and night are due to Earth's rotation

Earth is roughly a sphere, and it spins on its own **axis**. A full day is 24 hours, the time Earth takes to complete a full rotation on its axis. Viewed from the North Pole, Earth **rotates** in an anticlockwise direction. This means the Sun appears to rise in the east and set in the west. At any time, half of Earth is in daylight and half is in darkness. The side facing the Sun has day, and the side facing away from the Sun has night.

Figure 7.2: Viewed from the North Pole, Earth rotates around its axis in an anticlockwise direction. The side of Earth facing the Sun is in daylight.



Earth's rotation was proven by the French scientist Léon Foucault (1819–68). Foucault built on the work of other scientists, who had observed that objects seemed to move across the horizon. To prove this idea, Foucault built a **pendulum** that swung from a fixed point. Over a 24-hour period, the pendulum changed direction slowly, demonstrating that Earth rotates constantly.

The Moon revolves around Earth

Moons are small bodies that **orbit** planets. They can be spherical or irregularly shaped. In our solar systems. Mercury and Venus do not have any moons, Earth has one, Mars has two and Saturn has 146!

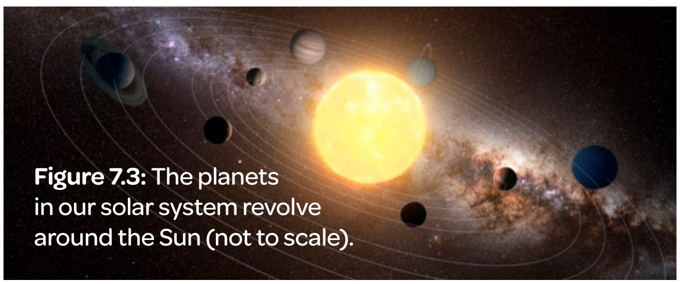


Figure 7.3: The planets in our solar system revolve around the Sun (not to scale).

Our Moon takes about 27 days to revolve around Earth and to rotate fully on its axis. This is why the same side of the Moon is always facing Earth.

Whenever the Moon passes over the side of Earth that is in daylight, it can be seen at the same time as the Sun. When the Moon is on the daylight side of Earth, the side of Earth that is experiencing night has no visible moon.

Galileo Galilei (1564–1642) was one of the first astronomers to use a telescope. He made detailed diagrams of the surface of the Moon and proposed that the large darker patches were seas (*maria*). He also observed four moons orbiting around Jupiter – the first moons to be discovered other than our own.

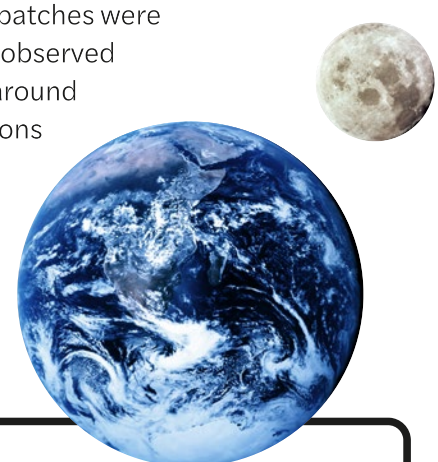


Figure 7.4: The same side of the Moon always faces Earth.

Learning Ladder

Earth, the Sun and the Moon

1. Copy and complete these sentences.
   - **a** The Sun is a _______ at the centre of our solar _______ .
   - **b** Earth is one of eight _______ that revolve around the _______ .
   - **c** _______ are small bodies that _______ planets.
2. Identify if the following statements are true or false. If the statement is false, rewrite it so that it is true.
   - **a** It takes Earth 365 years to revolve around the Sun.
   - **b** At any time, half of Earth is in daylight and half is in darkness.
   - **c** The Sun appears to rise in the west and set in the east.
   - **d** The same side of the Moon is always facing Earth.
3. **a** Explain the cause of day and night.
   b Outline how this is different to the Earth's revolution.
4. Galileo thought that the moon has 'seas'. Propose what we understand these to be today, and outline how better telescopes have changed our understanding.
5. Analyse how the rotation of Earth impacts society.

Nature and development of science

1. Identify Foucault's solution to proving that Earth rotates:
   - **A** Careful measurements
   - **B** Observations of night and day
   - **C** Pendulum
   - **D** Telescope
2. Propose why scientists must collaborate to further our understanding of the solar system.
3. Explain how the telescope allowed Galileo to contribute to changing scientific understanding of the solar system.

Questioning and predicting *p. 222*

1. From the following, identify the scientific question(s) that could be answered by making observations of the movement of the Sun or the Moon over a period of time.
   - **A** How big is the Sun?
   - **B** How long does it take for the Moon to cycle through all of its different phases?
   - **C** How did the Moon form?
2. Predict what you would observe in order to be able to answer the question(s) you selected for Question 1.
3. Construct your own scientific question that you could answer by making observations of the movement of the Sun or the Moon over a period of time.

Key idea: Systems

Compare and contrast the Earth and Moon system with the Earth and Sun system.

Success criteria

- I can identify key features of our solar system.
- I can demonstrate what causes day and night.

7·2 ▸ Models of the universe

Learning intention

At the end of this lesson, I will be able to explain, using examples, how scientific knowledge and understanding of the solar system changes as new evidence becomes available.

Key terms

evidence: facts and information that give reason to believe that something is true

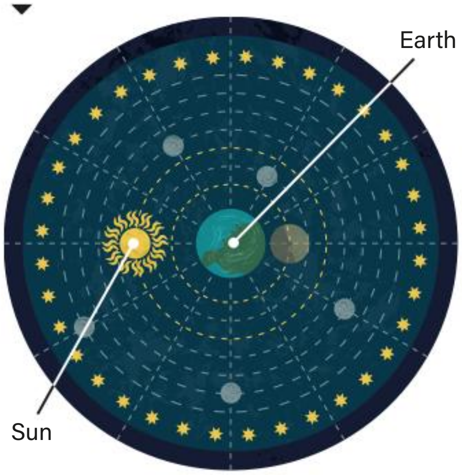
geocentric model: a model of the solar system with Earth at the centre

heliocentric model: a model of the solar system with the Sun at the centre

model: a physical or mathematical representation of a scientific idea or concept

Key idea: Systems

Figure 7.5: The geocentric model placed Earth at the centre of the universe with the Sun and the planets revolving around it.



The early models developed by ancient peoples to try to explain Earth's relationship to the rest of the observable universe were modified or rejected over time as a result of new scientific evidence.

The geocentric model put Earth at the centre of the solar system

One of the first **models** of the solar system was the **geocentric model** (see Figure 7.5). The word 'geocentric' comes from 'geo' (Earth) and 'centric' (centred).

According to the geocentric model:

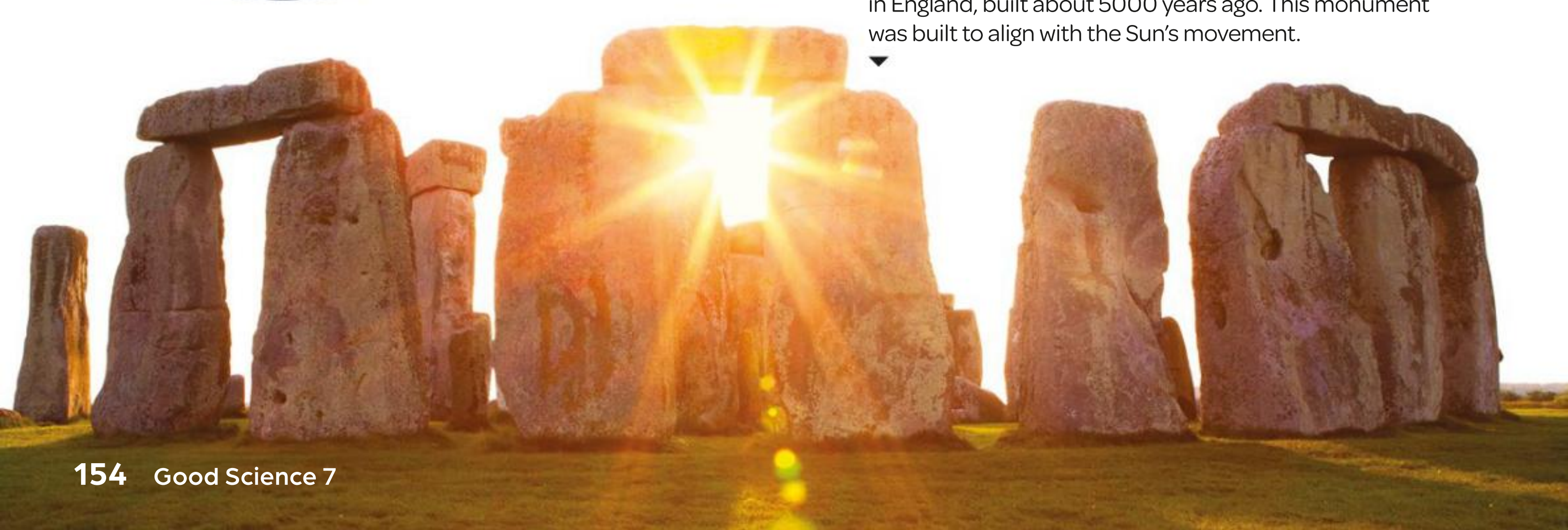
- Earth was a sphere.
- Earth was at the centre of the solar system.
- Earth did not move.
- The Sun and the planets revolved around Earth.
- As the Sun and planets travelled around Earth, they also simultaneously moved around their own small circular paths.

The ancient Greek philosopher Aristotle (384–322 BCE) argued in favour of the geocentric model. Aristotle wrote about astronomy and made his observations with only the naked eye.

Another early scientist who agreed with the geocentric model was the Egyptian astronomer Ptolemy (100–170). He agreed that Earth was at the centre of the solar system, but he suggested that the planets and the Sun revolved around a point outside Earth.

Aristotle's and Ptolemy's observations provided early scientists with **evidence** that supported the hypothesis that Earth was at the centre of the solar system. The geocentric model became the accepted view for more than 1500 years. However, as time passed and mathematics and technologies developed, new evidence changed these initial hypotheses, and modified models of the solar system were developed.

Figure 7.6: Stonehenge is a circle of standing stones in England, built about 5000 years ago. This monument was built to align with the Sun's movement.



The heliocentric model put the Sun at the centre of the solar system

In the 16th century, the **heliocentric model** replaced the geocentric model as the accepted model of the solar system. This model placed the Sun at the centre of the solar system (see Figure 7.7).

The heliocentric model was created by the Polish astronomer Nicolaus Copernicus (1473–1543), who used mathematics to explain the motion of objects in the heavens. His model proposed that:

- the Sun was at the centre of the solar system
- Earth and the other planets revolved in their orbits around the Sun.

Galileo's observations of the solar system using a telescope provided evidence that overwhelmingly supported the heliocentric model.

Many people rejected the heliocentric model, because it suggested that humans were not the most important beings in the universe. The early Catholic Church punished many people who believed in the model, including Galileo. Eventually, the heliocentric model was accepted around the world.

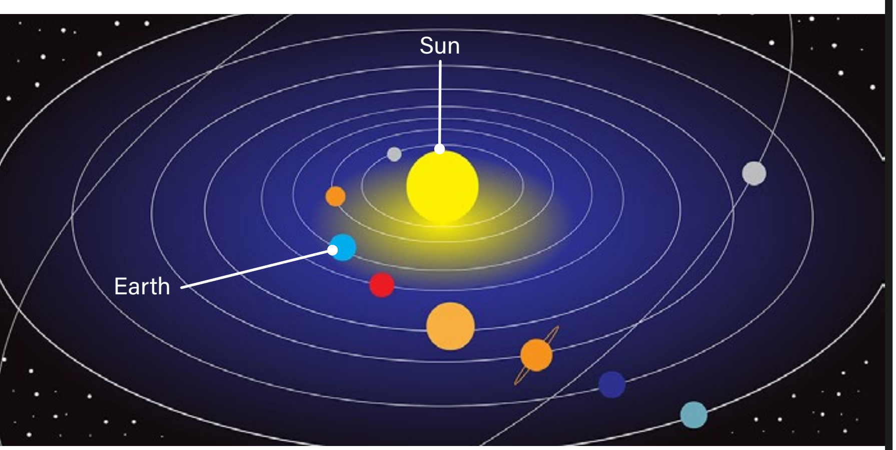


Figure 7.7: The heliocentric model placed the Sun at the centre of the solar system with the planets revolving around it.

As telescopes developed, people noticed that stars did not orbit the Sun. By the early 19th century, scientists realised that although the Sun is the centre of our solar system, it is not the centre of the universe.

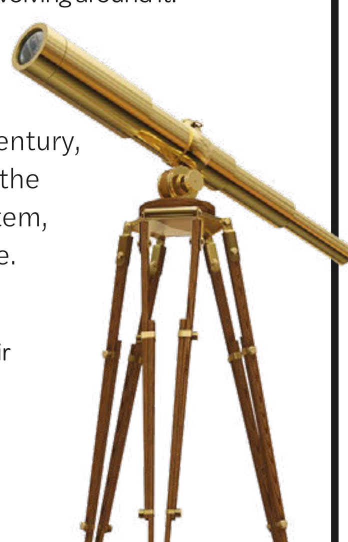


Figure 7.8: By using telescopes like this one, early scientists improved their understanding of the solar system.

Learning Ladder

Earth, the Sun and the Moon

1. Identify the key features of the:
   - **a** geocentric model.
   - **b** heliocentric model.
2. Describe the contributions towards our current understanding of the solar system made by:
   - **a** Aristotle.
   - **b** Ptolemy.
   - **c** Copernicus.
   - **d** Galileo.
3. Create a Venn diagram to compare and contrast the geocentric and heliocentric models.

Nature and development of science

1. Copy and complete:
   - **a** The __________ model was developed based on observations made with the ___________.
   - **b** Copernicus used __________ to explain the motion of objects in the heavens and developed the _________ model.
2. Propose two areas of scientific knowledge that may have been needed to invent the telescope. Provide a reason for your response.
3. Explain how the evidence presented by Copernicus and Galileo led to the acceptance of the heliocentric model.
4. Discuss how different models of our solar system and the universe developed over time. Use examples and diagrams in your response.
5. Analyse how Copernicus and Galileo both developed evidence to support the heliocentric model.

Questioning and predicting p. 222

1. Propose a question about the geocentric or heliocentric model that could be investigated scientifically.
2. We know that some planets in our solar system have no moons, some have a few and others have many. Predict if there would be moons orbiting planets in other solar systems. Explain your response.

Key idea: Systems

Imagine you are presenting evidence for the heliocentric model of the universe. Identify and justify two pieces of evidence that support this model.

Success criteria

- I can explain how historical models of the solar system changed over time as new evidence was discovered.

7·3 ▸ Seasons

Figure 7.9: In Australia, spring features warming temperatures and many flowering plants, such as this red flowering gum.

Learning intention

At the end of this lesson, I will be able to describe how cyclical changes in the relative positions of Earth, the Sun and the Moon cause predictable phenomena on Earth, including seasons.

Key terms

equinox: the two times each year when night and day are about the same length

solstice: the two times each year when night and day are the most different in length

tilt: a sloping position or lean

Investigation 7.3

Modelling the seasons, p. 331

Key idea: Systems

Table 7.1: Melbourne's average maximum temperature throughout the year. Can you identify the different seasons based on temperature?

Month	Average maximum temperature (°C)
January	26
February	27
March	24
April	21
May	17
June	15
July	14
August	16
September	18
October	20
November	22
December	24

Ice cream and the beach. Crunchy leaves and warm jackets. Hot drinks and beanies. Beautiful flowers and the first warm weather after the cold. Which of the seasons is your favourite? Did you know that the tilt of Earth on its axis is why we have seasons?

Different places experience different seasons

We describe a season as a time of the year when we experience particular climatic conditions. In summer it is hot, in winter it is cold, and spring and autumn are somewhere in between. The northern and southern hemispheres experience opposite seasons. When it is summer in the southern hemisphere, it is winter in the northern hemisphere – and vice versa. The closer you are to the North and South Poles, the greater the difference in temperature between winter and summer.

Close to the equator, there is not much difference in temperature over the year. In these areas, seasons are determined by how much rainfall there is. Northern Australia has a wet season from October to March and a dry season from April to September.

Australian First Nations Peoples recognise different seasons, depending on their location. Rather than just using temperatures, they use other observations to know what weather to expect in the coming weeks and months.

The tilt of Earth's axis causes the seasons

Earth's axis is tilted about 23.5° compared to the path it takes around the Sun. This means that the different hemispheres receive different concentrations of the Sun's energy. When a hemisphere experiences summer, it is tilted towards the Sun: the Sun's energy is more concentrated and the temperature is higher. During winter, the Sun's energy is spread out over a larger area and so the temperature is lower. The amount of energy arriving at the tropics does not vary much from month to month and so the temperature remains consistent over the year.

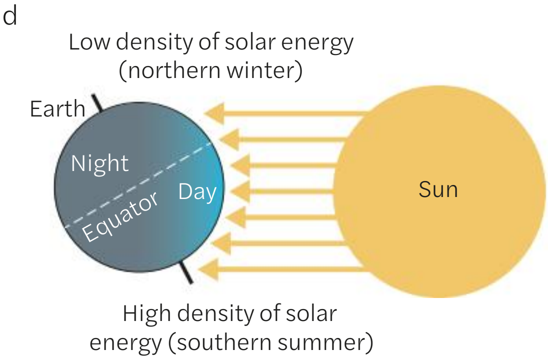


Figure 7.10: The seasons are caused by the tilt of Earth's axis. During winter the Sun's energy is spread out over a larger area, making it cooler. During summer the Sun's energy is more concentrated, making it warmer.

Equinoxes and solstices

Because of the tilt of Earth's axis, we experience different amounts of daylight hours and night hours as Earth orbits around the Sun. The equinoxes and solstices mark specific points in Earth's orbit (Figure 7.11).

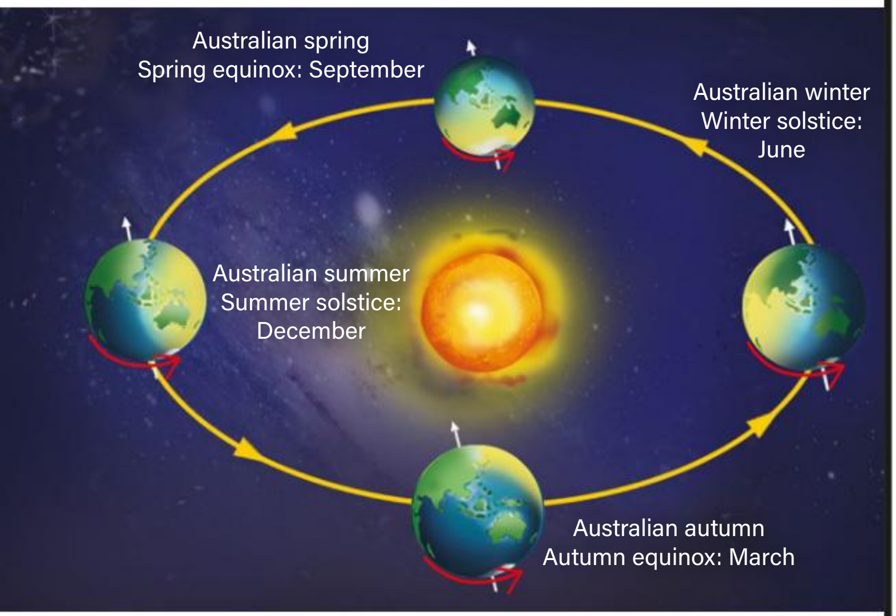


Figure 7.11: The tilt of Earth means that different countries have more or less direct sunlight, depending on where Earth is in its revolution around the Sun. Earth's tilt also results in equinoxes and solstices.

A **solstice** is a day when there is the largest difference between the number of hours of daylight and of darkness. For example, the winter solstice marks the shortest day and the longest night, while the summer solstice marks the longest day and the shortest night. If you were at the South Pole during the summer solstice, the Sun would not set!

The spring and autumn equinoxes mark the halfway point between the solstices. An **equinox** is a day when there is 12 hours of daylight and 12 hours of night. If you were at the equator during an equinox, the Sun would be directly overhead at 12 noon.

Table 7.2: Equinox and solstice dates around the world

Event	Approximate date	
Equinox	*23 September* and *20 March* worldwide	
Solstice	*21 June:*	winter solstice in southern hemisphere and summer solstice in northern hemisphere
	21 December:	summer solstice in southern hemisphere and winter solstice in northern hemisphere

Learning Ladder

Earth, the Sun and the Moon

1. Copy and complete these sentences.
   - **a** When the southern hemisphere has summer, the northern hemisphere has ________ .
   - **b** The seasons are caused by the ________ of Earth's axis.
2. Describe the difference between an equinox and a solstice.
3. Construct a diagram similar to Figure 7.10 to show the relationship between the tilt of Earth and the Sun when the southern hemisphere is experiencing winter.
4. Compare how the concentration of the Sun's energy, and therefore the temperature, varies across different seasons in Victoria. How would this compare to Darwin, which is close to the equator?

Nature and development of science

1. A common misconception is that summer is caused by the Earth being closer to the Sun. Explain why this is not true.
2. Describe why astronomers, farmers and meteorologists should collaborate when planning when to plant crops.

Processing, modelling and analysing *p. 230*

1. Identify the date of the:
   - **a** Australian summer solstice.
   - **b** Australian spring equinox.
   - **c** next solstice or equinox.
2. Use the data in Table 7.1 to distinguish between the different seasons (spring, summer, autumn, winter).
3. Construct a graph of Melbourne's temperature data. Label the seasons.
4. Australia starts new seasons on the first day of a month. Some countries use the solstices and equinoxes to determine the seasons. Using the graph from Question 3 and Table 7.2, discuss whether one approach is better.
5. Melbourne has many days well over 30 °C. Analyse the data in Table 7.1, and explain why the temperature data appears so low in Melbourne's summer.

Key idea: Systems

Identify the season when an astronomer would have longer nights to make more observations. Justify your answer.

Success criteria

- I can use a simple model or diagram to show what causes the seasons.
- I can explain what causes the seasons.

7.4 ▸ Eclipses

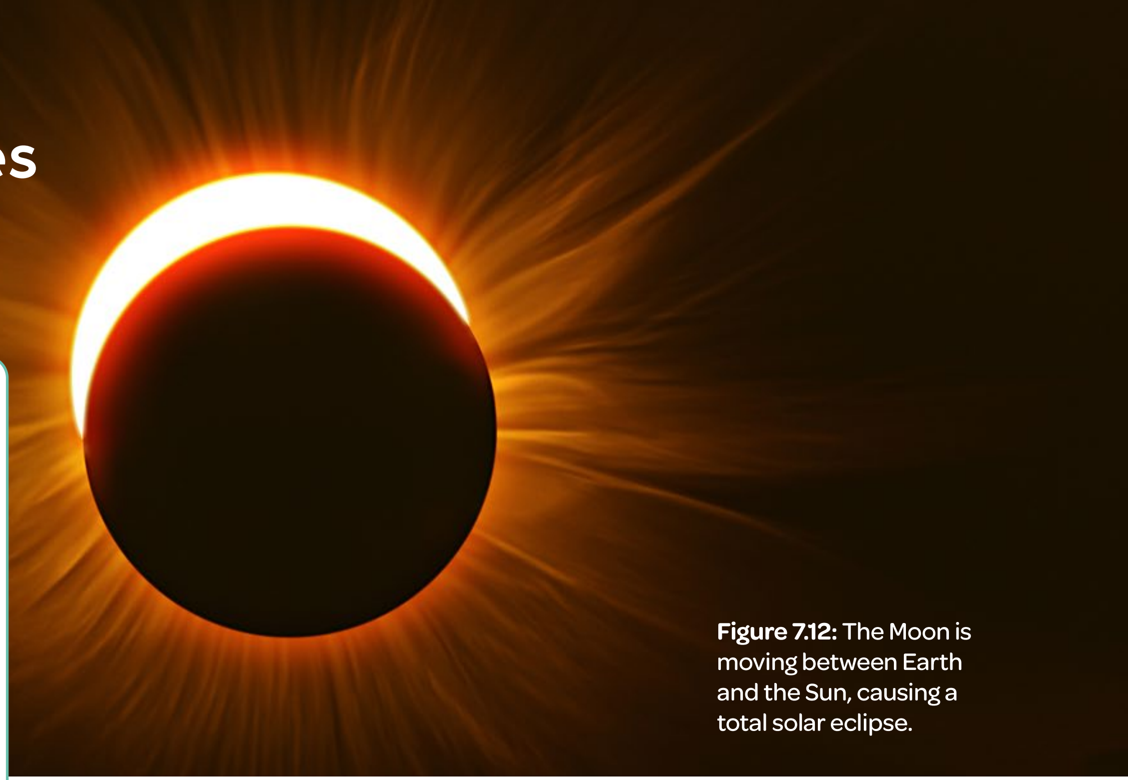


Figure 7.12: The Moon is moving between Earth and the Sun, causing a total solar eclipse.

Learning intention

At the end of this lesson, I will be able to describe how cyclical changes in the relative positions of Earth, the Sun and the Moon cause eclipses.

Key terms

annular: ring-shaped

eclipse: the blocking of the Sun's light from Earth

penumbra: the outer part of the Moon's shadow on Earth

umbra: the inner part of the Moon's shadow on Earth

Investigation 7.4

Modelling eclipses, p. 332

Key idea: Systems

The Sun is about 400 times wider than the Moon and about 400 times further away from Earth than the Moon is. This means that, from Earth, the Sun and the Moon appear nearly the same size. There are times when Earth, the Moon and the Sun line up. These events are called **eclipses**.

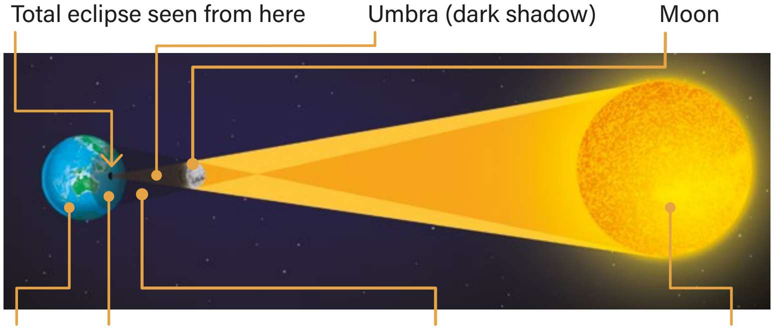


Figure 7.13: In a solar eclipse, the Moon casts a shadow over part of Earth.

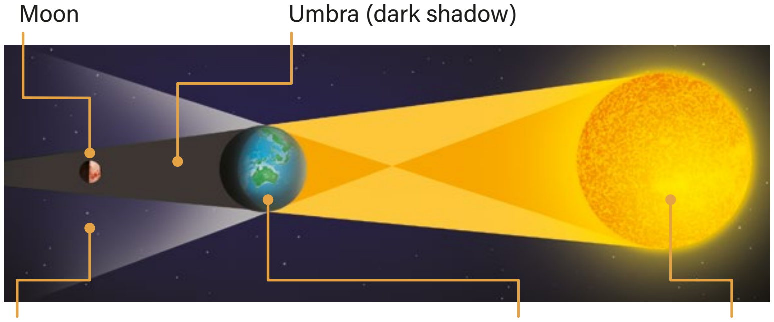


Figure 7.14: In a total lunar eclipse, the whole Moon is covered by Earth's shadow.

The Moon blocks the Sun's light during a solar eclipse

A solar eclipse occurs when the Moon passes between the Sun and Earth. The Moon blocks the Sun's light and casts a shadow on Earth. The centre of this shadow is the **umbra** and the outer ring of shadow is the **penumbra**.

There are three types of solar eclipse: total, annular and partial. They differ in how much light the Moon blocks, as seen by a viewer on Earth.

A **total solar eclipse** occurs when the Moon, Sun and Earth align (see Figures 7.12 and 7.13). People within the umbra see the Moon block *all* the Sun's light; those within the penumbra see the Moon block *part* of the Sun's light.

An **annular solar eclipse** occurs when the Moon is further away from Earth, making it appear smaller than usual. Because of this, the Moon only covers the centre of the Sun. During an annular eclipse, we can see the outer edges of the Sun. This is called an annulus or 'ring of fire'.

A **partial solar eclipse** occurs when the Sun, Moon and Earth are aligned but they are not positioned in a perfectly straight line. The Moon only blocks part of the Sun when this happens. There is no umbra in a partial solar eclipse; everyone who sees it is in the penumbra.

A solar eclipse happens during a 'new Moon', which means the Moon can be very difficult to see in the night sky. This is because the Sun's light is hitting the side of the Moon that is opposite the side facing Earth.

Earth blocks the Sun's light during a lunar eclipse

A lunar eclipse occurs when Earth passes between the Sun and the Moon. Earth blocks the Sun's light and casts a shadow on the Moon. Depending where you are on Earth during a lunar eclipse, some or all of the Sun's light is blocked.

Lunar eclipses always happen when the Moon is full, which is when the whole Moon can be seen in the night sky from Earth. There is a full Moon every 29.5 days. During most months, a full Moon occurs when the Moon does not line up with the Sun and Earth. During a lunar eclipse, the Sun, Earth and Moon are aligned.

There are three types of lunar eclipse: total, partial and penumbral. Each type of eclipse is named according to how much light is blocked by Earth, as seen by a viewer on Earth.

A **total lunar eclipse** occurs when the Sun, Earth and Moon are perfectly in line. The whole Moon is covered by Earth's shadow (see Figure 7.14). Total lunar eclipses are known as 'blood moons' because the Moon looks very red.

A **partial lunar eclipse** occurs when the Sun, Earth and Moon are not completely in line. Only part of the Moon is covered by Earth's shadow. During a partial lunar eclipse, you can see the curved shape of Earth's shadow on the Moon.

A **penumbral lunar eclipse** occurs when the Moon only passes through the penumbra, which is the outer edge of Earth's shadow. These eclipses are often not noticed because the Moon appears only slightly dimmer than a regular full Moon.

⚠ **NEVER** LOOK DIRECTLY AT THE SUN, INCLUDING DURING A SOLAR ECLIPSE. LIGHT FROM THE SUN CAN DAMAGE YOUR EYES. **ALWAYS** USE AN INDIRECT METHOD OF OBSERVATION, SUCH AS A PINHOLE PROJECTED ONTO ANOTHER SURFACE.

Learning Ladder

Earth, the Sun and the Moon

1. Identify the following statements as being true or false. If they are false, rewrite them to be true.
   - **a** Earth blocks the light of the Sun during a solar eclipse.
   - **b** Lunar eclipses always happen when the Moon is full.
   - **c** Partial eclipses happen when the Sun, Earth and Moon completely line up.
2. Copy and complete the following sentences.
   - **a** A solar eclipse happens when the ________ is in between the ________ and ________.
   - **b** A lunar eclipse happens when ________ is in between the ________ and the ________.
3. Construct a diagram to model a partial and a total solar eclipse.
4. In the past, some cultures thought eclipses were a supernatural event. Contrast this with our current scientific understanding.
5. Analyse ways in which eclipses may impact society

Nature and development of science

1. Propose whether eclipses can be predicted.
2. Propose how more than one type of scientist observing the orbits of Earth and the Moon can collectively improve our understanding of eclipses.

Evaluating

p. 239

Refer to Investigation 7.4, 'Modelling eclipses', on page 332, when answering the following questions.

1. Identify an assumption in the investigation related to the equipment used to model Earth and the Moon.
2. Describe two different types of errors that may be present in the method.

Key idea: Systems

Create a comic strip that outlines what happens during a solar eclipse and a lunar eclipse.

Success criteria

- I can explain what solar and lunar eclipses are, including how they occur.
- I can use a simple model or diagram to show what causes solar and lunar eclipses.

7.5 ▸ Phases of the Moon

Learning intention

At the end of this lesson, I will be able to describe how the phases of the Moon are caused by the relative positions of the Sun, Earth and Moon.

Key terms

Dreaming stories: important stories for First Nations Peoples; these stories often contain important knowledge of the world

waning: when the Moon looks as though it is getting smaller

waxing: when the Moon looks as though it is getting bigger

Investigation 7.5

Modelling the Moon's phases, p. 334

Key idea: Systems

The Moon is a constant in our sky, but it always appears to change. Sometimes we see a large and bright full Moon, or it could be a thin crescent, or not be there at all, or we may even see it in the daytime. Why does the Moon's appearance keep changing?

The Sun lights the Moon

The Moon does not produce its own light. Instead, the moonlight that we see is sunlight reflected off the light-coloured surface of the Moon. The Sun always lights up half of the Moon, so there is always a dark side and a light side. Because the Moon is orbiting Earth and Earth is orbiting the Sun, we do not always see the whole side of the Moon that is facing the Sun. Instead, we usually see part of the sunlit side and part of the dark side at the same time.

Phases of the Moon

As the Moon orbits around Earth, the amount of the sunlit side we can see changes, so the Moon appears to change shape. We call these different shapes 'phases'. The Moon takes about 29.5 days to cycle through these phases; this is also known as a lunar month. This is very close to the time it takes (27 days) for the Moon to make one revolution around Earth.

There are eight phases in a lunar month (see Table 7.3). When the Moon appears to be growing in size, we say it is **waxing**. When it appears to be getting smaller, we say it is **waning**.

We observe a full Moon when it is on the opposite side of Earth from the Sun and we see the entire sunlit side. We observe a new Moon when it is between Earth and the Sun and we do not see any of the sunlit side. We observe quarter moons when the Moon is halfway between these two points.

Figure 7.15: As the Moon orbits Earth, the amount of its sunlit side that we see from Earth changes. We call these 'phases'.

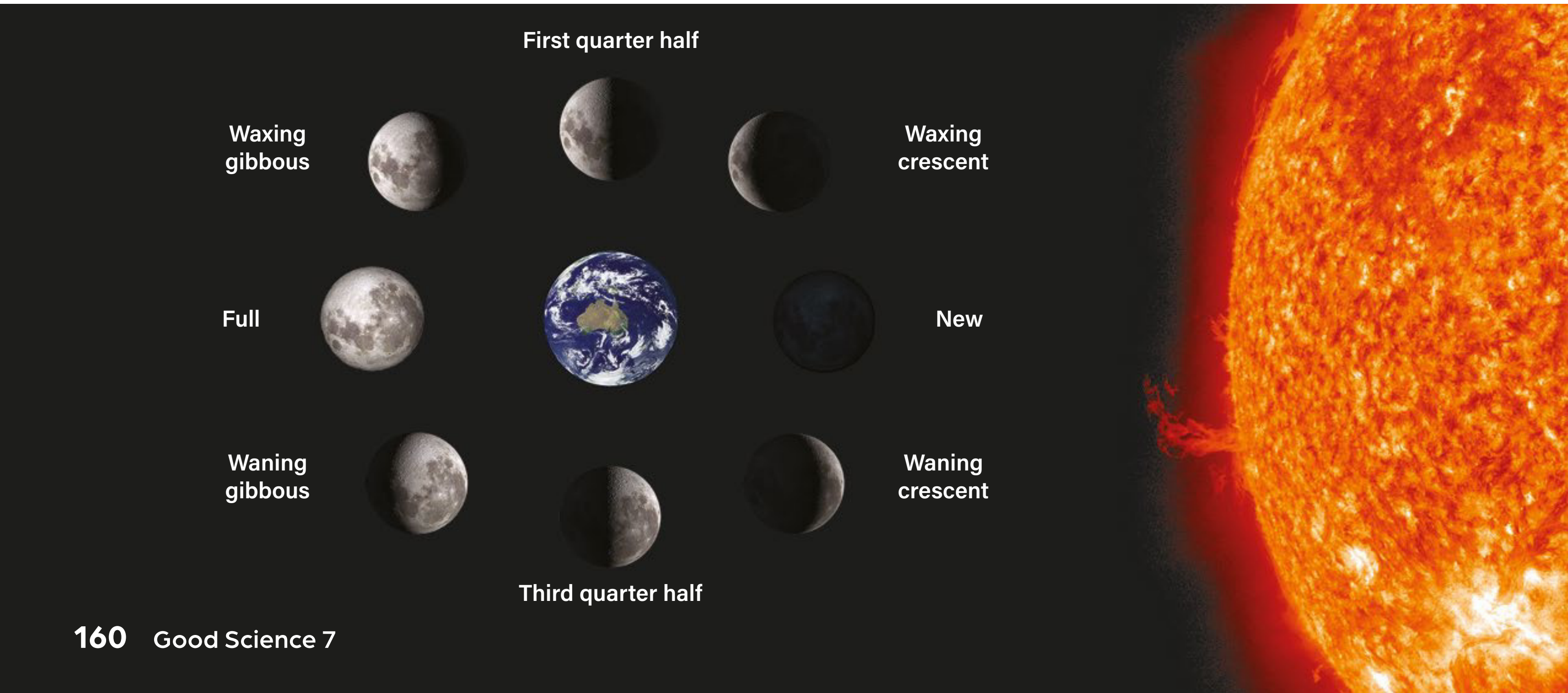


Table 7.3: Phases of the Moon

Phase of the Moon	What we see
New	The Moon is not visible in the sky.
Waxing crescent	A crescent is illuminated on the left side of the Moon.
First quarter	The left side of the Moon is illuminated.
Waxing gibbous	Most of the Moon is illuminated. Only a small crescent on the right side of the Moon is dark.
Full	The whole circular face of the Moon is illuminated, forming a full circle.
Waning gibbous	Most of the Moon is illuminated. Only a small crescent on the left side of the Moon is dark.
Third quarter	The right side of the Moon is illuminated.
Waning crescent	A crescent is illuminated on the right side of the Moon.

First Nations Peoples' understanding of the phases of the Moon

A First Nations account of the phases of the Moon is captured in the **Dreaming story** about Ngalindi (the Moon-man). This story is from the Yolŋu People.

This is how part of this story was told by a CSIRO astronomer, Ray Norris:

> 'In the Yolŋu story, [the Moon is] called Ngalindi. and he was big and round and fat like the full Moon, and he was lazy. His wives and children got so angry because he did nothing to help, so they chopped off bits of him and he went from being a round, fat Moon and got thinner and thinner, which is why you get phases of the Moon.
>
> Eventually he died and stayed dead for three nights before he came back to life, as a new Moon. He cursed everyone and said that when he died, he would come back to life, but when others died, they would stay dead.'

Learning Ladder

Earth, the Sun and the Moon

1. Identify the following statements as true or false. Rewrite false statements so that they are true.
   - **a** Moonlight is produced from chemical reactions inside the Moon.
   - **b** The amount of the Moon that is lit by the Sun changes over the lunar month.
   - **c** The term 'phase' is used to describe the different shapes of the Moon.
2. Describe the phase you would expect to observe if the Moon were located between Earth and the Sun.
3. Construct a table that shows the Moon's phases with the relative position of Earth, the Moon and the Sun, and what we see from Earth. Use Figure 7.15 to help you.
4. Compare a waxing gibbous Moon with a waning gibbous Moon.

Nature and development of science

1. Identify the correct answer that best explains the Yolŋu story of Ngalindi.
   - **A** The story explains how we can observe the Moon.
   - **B** The story explains how the Moon was formed.
   - **C** The story explains why the Moon gets larger and smaller over time.
   - **D** The story explains why there are craters on the Moon.
2. Describe how the Yolŋu Peoples' observations of the Moon are related to contemporary understandings.

Questioning and predicting

p. 222

1. Identify the question below that could be investigated by making observations of the Moon over a period of time.
   - **A** How can we observe the 'dark side' of the Moon?
   - **B** How does the phase of the Moon change over time?
   - **C** Why does the Moon have white craters and black craters?
2. Propose how you could use observations made of the Moon over a one-month period to predict when the next full Moon would be.
3. Construct a question of your own that could be addressed by making observations of the moon.

Use your scientific question from Question 3 to answer the following:

4. Construct a hypothesis that predicts the relationship between variables.
5. Explain whether your scientific question is likely to have high or low scientific validity.

Key idea: Systems

Use your knowledge of the Moon's phases to explain the impact the Sun has on what we observe in the night sky.

Success criteria

- I can describe the phases of the Moon.
- I can use a simple model or diagram to describe how the relative positions of Earth, the Sun and the Moon cause the phases of the Moon.

7·6 ▸ Tides

Learning intention

At the end of this lesson, I will be able to describe how tidal variations are caused by the relative positions of the Sun, Earth and Moon.

Key terms

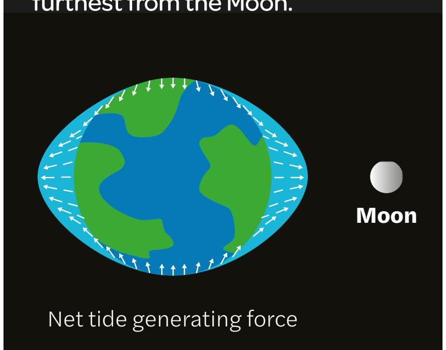
gravitational force: an indirect force that attracts physical objects with mass towards each other

tide: the rise and fall of the waters in the ocean, caused by forces from the Moon and the Sun

Key idea: Systems

If you walk along a beach at different times of the day, you will notice that the water level changes. Sometimes it is higher, covering much of the beach, and other times it is lower, exposing more sand and rock pools. These regular changes in the water level are known as **tides**, and they are caused by the **gravitational force** between Earth, the Moon and the Sun.

Figure 7.16: The Moon's gravitational pull on Earth causes the water in the oceans to bulge out on the sides closest to and furthest from the Moon.



Tides and the Moon's gravitational pull

Even though the Moon is around 384 000 kilometres away and is much smaller than Earth, we still experience the impacts of its gravitational pull. The Moon pulls ever so slightly at Earth, causing it to bulge outwards. Because water is easier to move than rock, we can observe the movement of the water due to this pull along the coastline as high and low tides.

The Moon's gravitational pull causes the water in Earth's oceans to bulge out on the sides closest to and furthest from the Moon (Figure 7.16). These bulges create high tides. As Earth rotates on its axis, the continents and islands move through these bulges and so coastlines will experience a high tide and a low tide twice a day.

The Sun's influence on tides

The Sun also influences the tides. Although it is much further away from Earth (around 147 million kilometres), the Sun's very large mass still has an influence on the tides. We observe this influence when Earth, the Moon and the Sun are aligned twice a month (at the full Moon and new Moon) and the combined gravitational pull of the Moon and the Sun cause very high tides known as spring tides. About a week after a spring tide, when the Moon and the Sun are at right angles to each other, the gravitational pull from the Sun cancels out a lot of the pull from the Moon, causing very low tides known as neap tides.

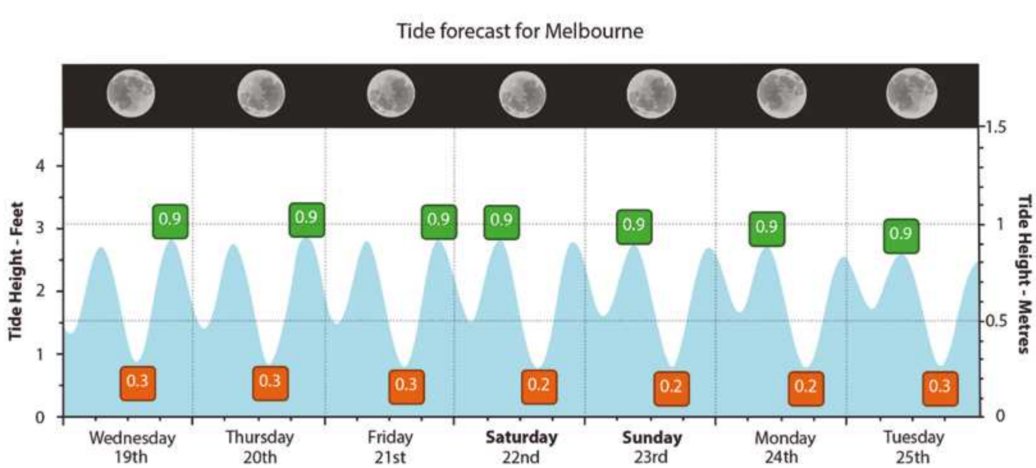


Figure 7.17: A seven-day tide chart for Melbourne. There are two high tides and two low tides each day, with each cycle taking approximately 12 hours.

A king tide is a type of spring tide that occurs twice a year, when the Moon is closest to Earth in its orbit at the same time as a full Moon or a new Moon. Because the Moon is slightly closer, it exerts more of a gravitational pull and so the bulge becomes larger, causing a very high tide.

Spring tides are also higher when Earth is closer to the Sun in its orbit.

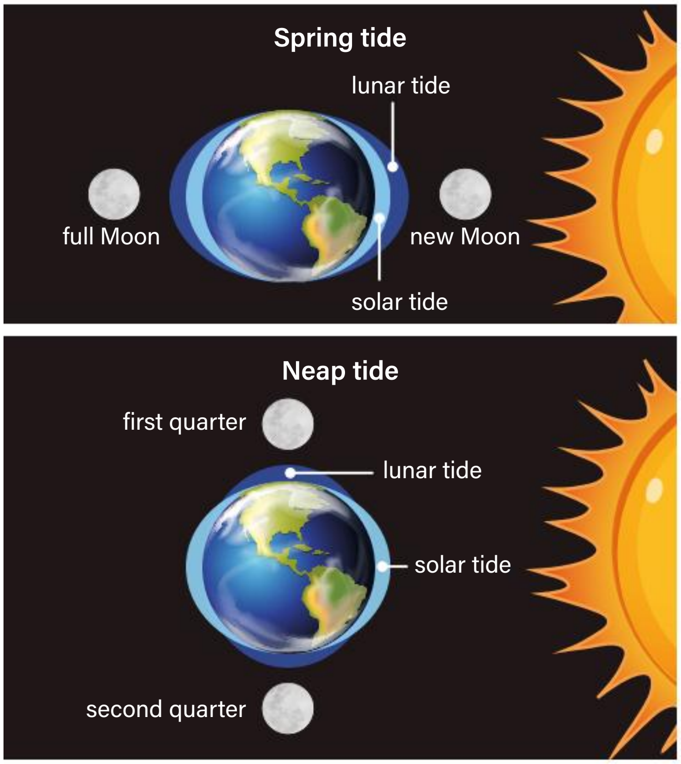


Figure 7.18: A spring tide is a very high tide caused by the combined gravitational pull of the Moon and the Sun. It occurs when Earth, the Moon and the Sun are aligned. A neap tide is a very low tide and occurs when the Moon is at right angles to the Sun.

First Nations peoples' understanding of the tides

First Nations Peoples have long recognised an alignment between what happens in the sky and what happens on Earth. They use this knowledge for many purposes. For example, by observing how the positions and phases of the Moon correlate with the ebb and flow of tides, they can predict a tide's timing and height. Tidal fish traps built by some First Nations Peoples consist of stone walls that create pools or pens. At high tide, these walls are submerged, allowing fish to swim into the area. As the tide ebbs, the water level drops, trapping the fish in the pools.

Learning Ladder

Earth, the Sun and the Moon

1. Copy and complete:
   - **a** The ________ gravitational pull on ________ causes water in the oceans to bulge out.
   - **b** There are ________ high tides and two low tides in a ________ hour period.
   - **c** The ________ also has an influence on ________ .
2. Describe how the Moon impacts Earth's tides.
3. Construct a diagram that shows the position of Earth, the Moon and the Sun during a king tide.
4. Explain the tides that you would observe at a full Moon as compared to a quarter Moon.

Use and influence of science

1. Propose a problem that First Nations Peoples solved by observing the phases of the Moon and ocean tides. Summarise the solution.
2. Describe the importance of being able to predict tides.
3. Explain how knowledge about tides enabled First Nations Peoples to build fish traps.
4. Discuss how ancient First Nations coastal communities would have used their knowledge of tides.
5. Analyse the possible importance for modern Australian coastal communities of sharing First Nations Peoples' understanding of tides .

Evaluating *p. 239*

A group of students was collecting data that compared the height of the ocean at a jetty and the phase of the Moon. Different students took measurements over the month. Their method was: *Go to the jetty and measure the height of the water twice during the day. At night, record what phase the Moon is in.*

1. Identify at least two sources of error in their method.
2. Describe how these errors could impact the data that is gathered.
3. Use your understanding of tides to write a paragraph that explains the relationship between the height of the tides and the phases of the Moon.

Key idea: Systems

Analyse this statement:

'If there was no Moon, there would be no tides.'

Success criteria

- I can describe what causes tides.
- I can use a simple model to describe how the relative positions of Earth, the Sun and the Moon cause tides.

7·7 ▸ First Nations Peoples' use of the stars

Figure 7.19: Whirlwinds are common when the Scorpius constellation can be seen in the sky.

Learning intention

At the end of this lesson, I will be able to describe some of the many ways First Nations Peoples use their observations of the stars, including predicting seasonal events.

Key terms

brumation: the state of dormancy (inactivity) reptiles undergo in winter (similar to hibernation)

diffuse: when light becomes spread out as it passes through the atmosphere

sky Country: in First Nations knowledge, the aspects of Country that are not linked to the land; all the observable celestial phenomena and the spirits and lore linked to these events

songlines or song series: complex ways that First Nations Peoples record important information relating to many different topics; a body of songs sung sequentially, and which are intended to convey knowledge

Key idea: Systems

Aboriginal and Torres Strait Islander Peoples have long used their observations of the stars to predict weather, identify when the seasons will change, predict animal behaviour and identify the best time to source different foods.

First Nations astronomers know sky Country

The stars are an important part of First Nations Peoples' knowledge and understanding of the world. First Nations Peoples have used oral stories, songs, **songlines**, dances and art to transmit this knowledge from generation to generation.

First Nations astronomers

Aboriginal and Torres Strait Islander communities have their own astronomers. These are individuals who are selected to be trusted with knowledge of the stars. In the western Torres Strait, these astronomers are called 'Zugubau Mabaig', meaning 'star man'.

First Nations astronomers are responsible for carefully watching the sky and noticing the most subtle changes in the position and properties (brightness, colour) of the stars. They fuse their observations with their vast knowledge of the **sky Country**, and then advise the community on a range of issues, such as when to harvest certain foods. This practice is often referred to as 'reading the stars'.

Stars are used to predict the weather

Aboriginal and Torres Strait Islander Peoples use their observations of the stars to predict many different weather patterns.

Twinkling stars

In the eastern Torres Strait – north of Cape York in Queensland – Meriam Elders use the stars to predict rainfall and wind. The Elders know that when they observe twinkling stars towards the end of the year (in December), this predicts the start of the northern Australian monsoon season (the wet season) and the shift in the winds from cooler, drier south-easterlies to hotter, wetter north-westerlies.

This knowledge is preserved in the Meriam song 'Uier Naskaisreda' ('The Twinkling Stars'):

Aipki- em pemut bapiti-e
Nalugem pe-ueir Naskais-reda
Ur Kakaper ise Bapri-eda
Karim nowag-em e
Ziai giru baz-pe aisli
No-wabim MDW em di-kir
Nalu-gem pe-wer Naskais-reda

Why is it so calm tonight?
Why are the stars twinkling like embers?
Me, I think it's because of the big wind.
The clouds are coming from the south
And being swept to the north-west.
Why are the stars twinkling like embers?

— 'Uier Naskaisreda', song by George Passi

The stars appear to twinkle at this time of year because the hot, humid and windy conditions interfere with the light from the stars as it passes through the atmosphere, increasing how much the light shifts.

Blue, fuzzy stars

Elders know that when the stars look blue and fuzzy, it will rain soon. The stars look blurry because higher levels of water in the atmosphere (humidity) cause the light from the stars to **diffuse**.

Bunjil

The Wurundjeri People explain their understanding of how celestial events can influence life on Earth through the story of Bunjil the Eagle, which tells of how a star fell to Earth to create life. Bunjil's origin as a falling star emphasises the relationship between Country and Sky Country, connecting knowledge of the planets, the creation of Earth, the tides and the stars. In many Aboriginal cultures, tides and bodies of water are thought to be governed by ancestral beings who maintain balance in nature, as told in the story of Mindi the Great Snake. The story of Bunjil reflects Aboriginal knowledge of the interconnectedness of all things. The land, water, creatures and celestial bodies are all part of a harmonious system. Sustainability relies on understanding these connections.

Figure 7.20: There is a 25-metre sculpture of Bunjil at Docklands in Victoria.

Stars are used to predict animal behaviour and to identify when to source different foods

The rising and setting of particular stars at dusk and dawn are closely linked to Aboriginal and Torres Strait Islander Peoples' stories about the behaviour of animals (for example, when particular animals breed, give birth and migrate) and the availability of different foods.

The Emu in the Sky constellation

For the people who live in the Kamilaroi and Euahlayi Countries, the position of the Emu in the Sky constellation indicates different stages in the emu breeding season.

The shape of an emu can be seen in the dark patches in the Milky Way between the Coalsack Nebula (the emu head), the constellations of Scorpius and Sagittarius (the emu body), and the constellations of Ophiuchus and Aquila (the emu legs) (see Figure 7.21).

When the emu appears to rise in the sky at dusk (in April and May), this indicates that it is emu breeding season and it is the best time to collect emu eggs for food.

When the position of the emu in the sky changes (around August or September), it is time to stop collecting emu eggs, for two reasons. First, there needs to be enough emu hatchlings to maintain an emu population. Second, the emu chicks have been developing in the fertilised eggs and are not suitable for eating.

Figure 7.21: The shape of an emu can be seen in the dark bands of the Milky Way.

The Arcturus star

In Arnhem Land, the Yolŋu People harvest the corms (underground stems) of spike-rush plants (see Figure 7.22) when the Arcturus star can be seen in the sky just before sunrise.

Corms are usually at their biggest after several weeks of rainfall. Approximately 90 per cent of the annual rainfall in northern Australia occurs in the wet season (November to March). So, the optimal time to harvest spike-rush corms is late November, which is when the Arcturus star is around 10 degrees above the horizon at sunrise.

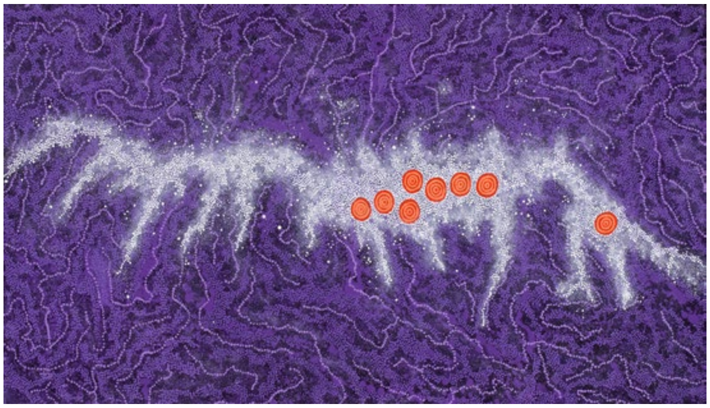
The Arcturus star is known as Marpeankurruk by the Boorong People, whose Country is near Lake Tyrell in north-west Victoria. The appearance of Marpeankurruk in the night sky in August coincides with the hatching larvae of the carpenter ant. These larvae can be found under logs and small rocks. They are high in protein and can be cooked or eaten raw. This ant's larvae can survive harsh droughts, so they are an excellent food source during dry periods.

Figure 7.22: The spike-rush plant is an important food source for First Nations Peoples who live in northern Australia.

Seven Sisters (Pleiades) star cluster

The Pitjantjatjara People – whose Country is the Central Australian Desert, near Uluru – use the appearance and position in the night sky of the Seven Sisters (Pleiades) star cluster to predict the beginning of the winter frost. They know that when the winter frost begins, many reptiles go into **brumation** and therefore these animals cannot be hunted at this time of year.

Figure 7.23: This is a painting of the Seven Sisters star cluster by Gabriella Possum Nungurrayi.



Gabriella Possum Nungurrayi,
Anmatyerre People, Northern Territory,
born Mt Allen, Northern Territory, 1967.
Seven Sisters, Milky Way Dreaming
2002, Melbourne.
Synthetic polymer paint on canvas
115.0 × 204.0 cm.
Santos Fund for Aboriginal Art 2002
Art Gallery of South Australia, Adelaide

20022P8

The First Nations People of the Central Australian Desert also know that when the Seven Sisters star cluster rises in the sky at dawn (in June), dingoes begin having their pups. This knowledge affects decisions about how to manage Country to make sure there are plenty of small animals for the dingoes to hunt to support the nursing dingo mothers and their newborn pups.

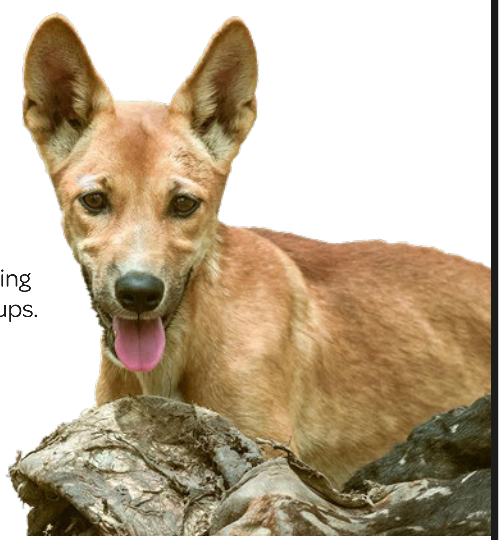


Figure 7.24: Dingoes have pups once a year; June to August are critical feeding months for newborn pups. The start of this period corresponds to when the Seven Sisters star cluster first rises in the sky at dawn.

The Kek star

In the Torres Strait, the appearance of the Kek star – also called the yam star and Achernar by Western astronomers – indicates it is time to begin harvesting yams. A yam is a root vegetable that grows underground. This means it is difficult to predict when yams are ready to be harvested without digging them up.

The best time to harvest yams is at the end of the wet season, when they have had plenty of water to help them grow and before the conditions of the dry season make them inedible.

The Kek star appears in late March, towards the end of the wet season. When Aboriginal and Torres Strait Islander Peoples see it, they know the dry season is coming.

Learning Ladder

Earth, the Sun and the Moon

1. Identify which constellation rising in the sky is often associated with the beginning of the dingo breeding season.
2. Describe how the Emu constellation relates to harvesting emu eggs.
3. Explain the importance of the appearance of Marpeankurruk to the Boorong people.
4. Compare and contrast how First Nations Peoples' knowledge is passed on across generations with Western methods of sharing information over time.
5. Analyse an example of First Nations astronomers using observation and their knowledge of sky Country to advise community decision-making.

Use and influence of science

1. Propose whether the appearance or disappearance of celestial bodies is an ethical, social, environmental or economic issue. Provide a reason.
2. Describe how observations of the stars could support land management practices in Australia.

Questioning and predicting *p. 222*

1. Propose a scientific question that you could ask about your observations of the Kek star in the night sky.
2. Predict the relationship between weather and twinkling stars.

Key idea: Systems

Create a table with a list of the celestial bodies mentioned in this spread. In the second column, match the observed phenomenon with the celestial body.

Success criteria

- I understand how the stars have been used by First Nations Peoples for thousands of years, and how these uses help to care for Country.

7.8 ► The technology of discovery

Learning intention

At the end of this lesson, I will be able to explain, using examples, how scientific knowledge and understanding of the universe changes as new technology becomes available.

Key term

astronomer: a scientist who studies space and the objects within it

Investigation 7.8

Making a simple telescope, p. 336

Key idea: Systems

Figure 7.25: The James Webb Space Telescope was launched on 25 December 2021 and has begun to provide us with information about deep space.

When we look out into space, we are actually looking back in time to planets and stars that may be extremely similar to our Earth, or almost unimaginably different.

People throughout history have always been curious. Technology has allowed us to discover distant objects and events and to wonder about more things than ever before.

Edwin Hubble first calculated the true size of the universe

Until the early 20th century, **astronomers** thought that the entire universe consisted of just one group of stars. They thought that the universe was only a single galaxy, with the stars in it relatively nearby. In the 1920s, astronomer Edwin Hubble was studying a star in what was called the Andromeda Nebula. He worked with a 2.5-metre telescope at Mt Wilson in California. His observations led him to conclude that:

- Andromeda was not nearby, but very distant
- it was not a cloud of gas or nebula but a galaxy like ours (it is now known as the Andromeda Galaxy)
- there are an incredible number of galaxies in the universe
- each galaxy contains tens of millions of stars.

Hubble's observations completely changed our understanding of the universe!

Hubble went on to create a system to classify galaxies according to how they look. Also, he proved that the entire universe is expanding at the same rate everywhere. He is now considered to be one of the most important astronomers in history, and the Hubble Space Telescope is named after him.

Space telescopes

Over time, technology has been able to improve telescopes to allow astronomers to discover more detail about our universe. In recent decades, we have been able to launch telescopes into space to observe light and radiation that cannot be detected on Earth.

The Hubble Space Telescope was placed into orbit about 525 kilometres above Earth by the space shuttle *Discovery* in 1990. It has made over 1.5 million observations, and has provided astronomers with evidence that supports the big bang theory of the formation of the universe. It has allowed them to observe the collisions of distant galaxies, as well as to look closer to home, discovering moons around Pluto and tracking a comet colliding with Jupiter.

The James Webb Space Telescope was launched into space on 25 December 2021. It orbits the Sun and is about 1.5 million kilometres from Earth. The mirror and sensors on the telescope will allow it to peer back in time to observe the first galaxies born after the big bang, and to gather information about the formation of solar systems.

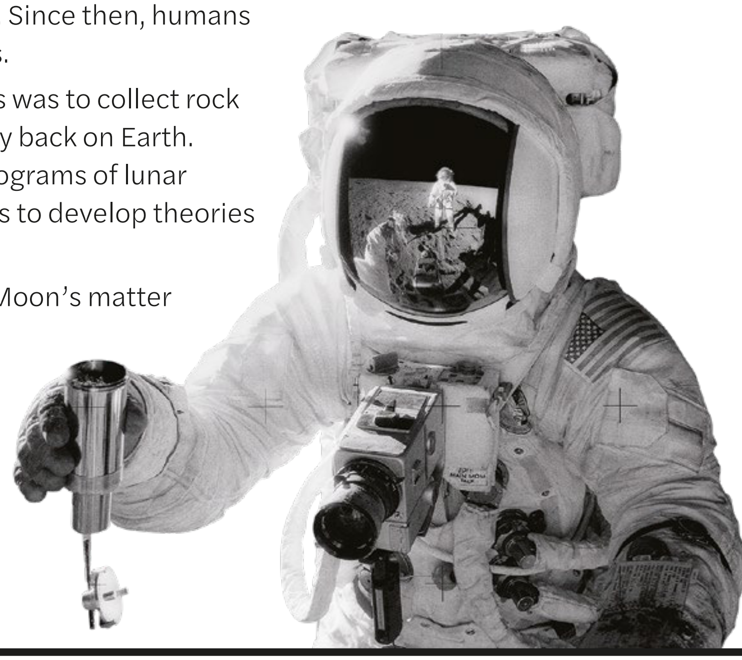
Humans first walked on the Moon in 1969

The *Apollo 11* mission was the first human-piloted effort to land on the Moon. Neil Armstrong, Michael Collins and Edwin 'Buzz' Aldrin Jr formed the crew on this historic mission. The US space agency, NASA, succeeded in its attempt on 20 July 1969. Since then, humans have landed on the Moon four more times.

One of the main aims of these missions was to collect rock samples from the Moon's surface for study back on Earth. The missions collected more than 382 kilograms of lunar samples. These samples allowed scientists to develop theories about the origin of the Moon.

Lunar samples show that some of the Moon's matter comes from Earth, and some comes from another source. The current theory for the Moon's origin is that a very young Earth was hit by a stray body about half its size. This collision threw debris out around Earth, which eventually collected together to form the Moon.

Figure 7.26: Astronauts collected lunar soil samples during the *Apollo 12* mission, the second human-piloted Moon landing.



Learning Ladder

Earth, the Sun and the Moon

1. Construct four statements about the technology of discovery that are true, and two that are false. Test these on a partner to see if they can work out which are true or false.
2. From the following list, choose the correct option. Until the work of Edwin Hubble, astronomers described the universe as being made up of:
   A many galaxies.
   B only our solar system.
   C one group of nearby stars.
3. Construct a diagram to represent Edwin Hubble's understanding of the structure of the universe.
4. Using an example, explain how technology has improved our understanding of the universe over time.
5. Analyse ways in which humans walking on the moon may have impacted society.

Nature and development of science

1. Identify two ways that space technology has improved models of celestial systems.
2. Describe some of the ways the first expedition to the Moon contributed to scientific understanding.
3. Explain how Edwin Hubble's discoveries changed the scientific understanding of our universe.

Processing, modelling and analysing *p. 230*

1. Use the information in the text to identify the distance from Earth of the:
   a Hubble Space Telescope.
   b James Webb Space Telescope.
2. The Moon is around 384 000 kilometres from Earth. Construct a labelled scale diagram that shows the positions of the Moon, the Hubble Space Telescope and the James Webb Space Telescope compared to Earth. Creating a scale is an example of a ratio. See 'Understanding ratios' in the Science how-to section on page 263.
3. Calculate how many times further away from Earth the James Webb Space Telescope is compared to the Hubble Space Telescope. For help with ratios, see the Science how-to section on page 263.

Key idea: Systems

The *Voyager I* and *Voyager II* spacecraft were launched in the 1970s with missions to explore our solar system. Conduct research into the discoveries they have made.

Success criteria

- I can describe how advances in telescopes and space exploration have helped to develop our understanding of the universe.

7.9 ▸ Key idea: Systems – our place in space

Learning intention

At the end of this lesson, I will be able to describe key components of the solar system.

Key terms

astronomical unit (AU): A unit of measurement that is equal to the average distance between Earth and the Sun – 147 million kilometres

gravity: the force of attraction between two objects

lightyear (ly): The distance light travels in one Earth year – 9 trillion kilometres

Investigation 7.9

Creating a scale model of the solar system, p. 337

Key idea: Systems

Our solar system consists of a star (the Sun), along with a group of planets and other objects bound together due to the gravitational force of the Sun. Space exploration has helped us to understand that our solar system is one of billions in the Milky Way galaxy.

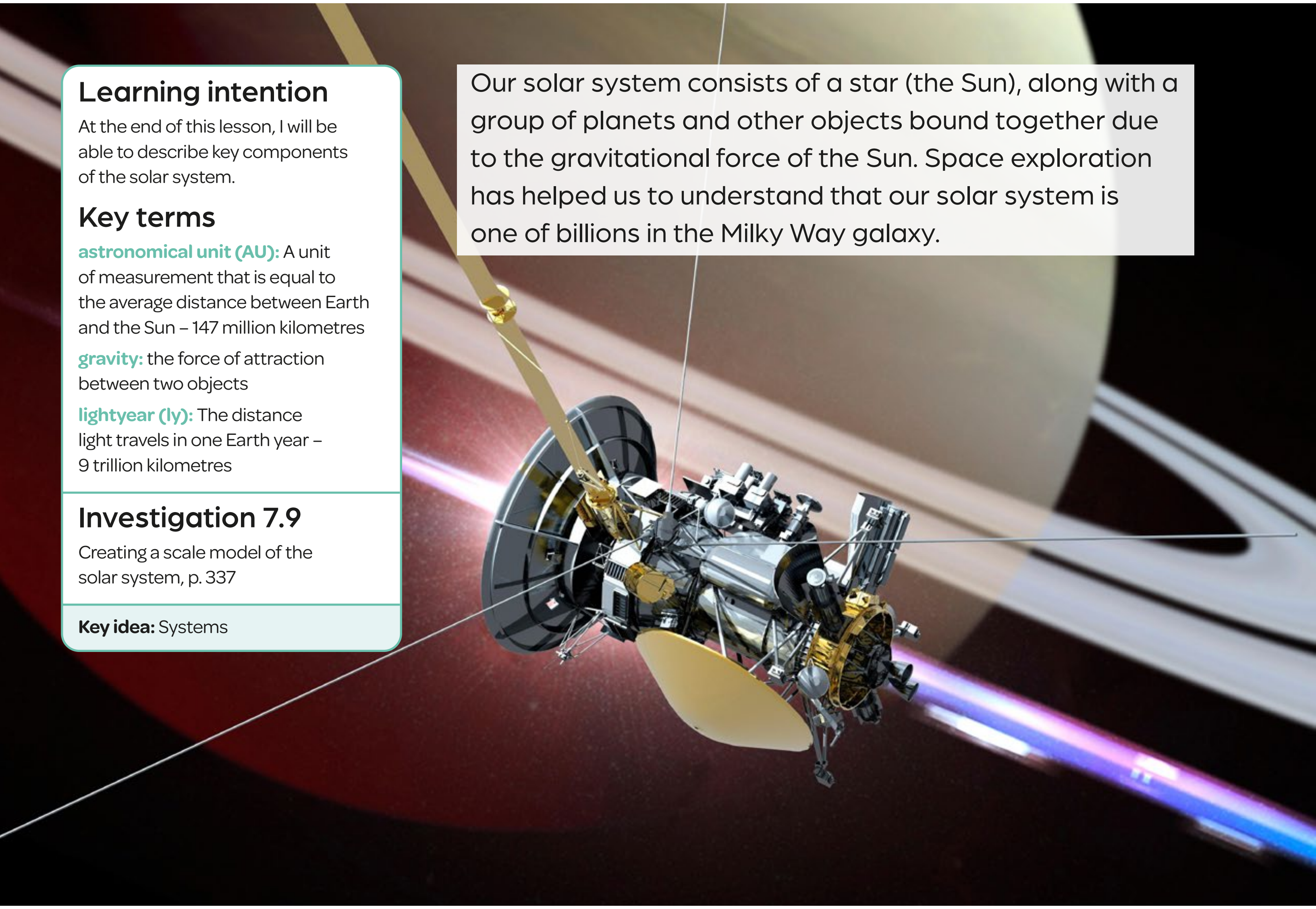


Figure 7.27: The *Cassini* spacecraft was launched in 1997. It spent from 2004 to 2008 exploring Saturn and its rings and moons.

Space is big

The distances between objects in space are so vast that astronomers have developed special units of measurement to describe them. The **astronomical unit (AU)** is used to describe distances within our solar system. One AU is equal to the average distance Earth is from the Sun (about 147 million kilometres). A **lightyear (ly)** is the distance light travels in one Earth year (approximately 9 trillion kilometres). It is 4.22 ly to Proxima Centauri, the star that is closest to our Sun.

Exploring our solar system

Since the 1950s, humans have sent out spacecraft to explore the solar system. Early missions focused on Earth and the Moon; however, probes have now visited every planet and many of their moons. Some missions have sent back valuable images and data gathered as they fly past objects. Others have been designed to land on the surface of planets, moons and asteroids in order to take samples that have been able to be analysed remotely. These missions have allowed us to build a deeper understanding of Earth and its place in our solar system. They have resulted in the invention of many new technologies that have applications in everyday life.

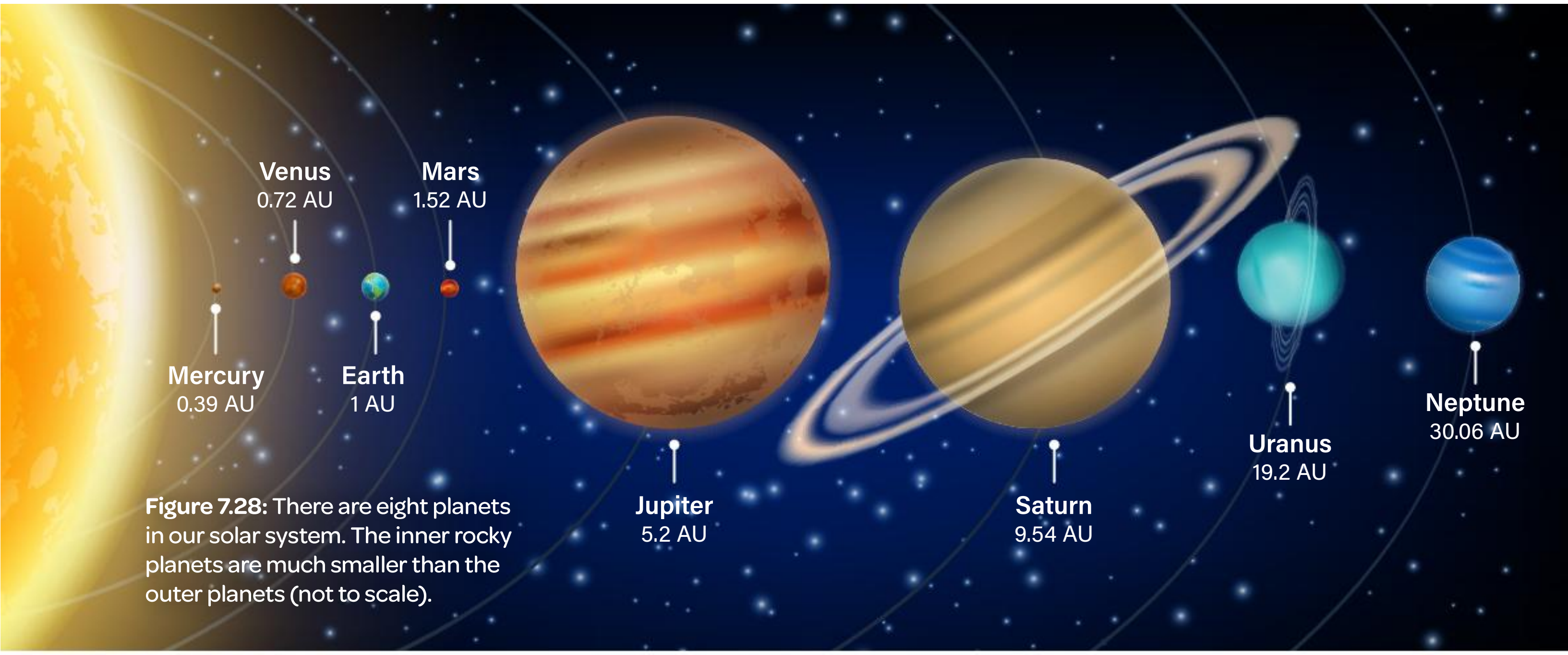


Figure 7.28: There are eight planets in our solar system. The inner rocky planets are much smaller than the outer planets (not to scale).

Planets

A planet is defined as a celestial body that is in orbit around a star, is spherical, and is large enough to have cleared away other objects in its orbit. There are eight planets in our solar system. Mercury, Venus, Earth and Mars are the rocky inner planets; Jupiter, Saturn, Uranus and Neptune are the outer giant planets made up of gas and ice. These planets are so large, they have many moons and a system of rings in orbit around them – like their own mini solar system. Saturn's rings are the most famous, but the other three giant planets have rings too. The rings are made of particles of ice, gas and dust. It is proposed that they formed from debris when one or many objects came too close to the planet and broke up.

While Mercury and Venus do not have any moons, Earth has one and Mars has two, the giant planets have many. Jupiter has 95 known moons. Ganymede is the largest moon in the solar system – it is larger than Mercury. Saturn has 146 moons. Titan is the largest of Saturn's moons – it is slightly smaller than Ganymede and is of interest to astronomers as it has its own atmosphere. Uranus has 28 known moons and Neptune has 16.

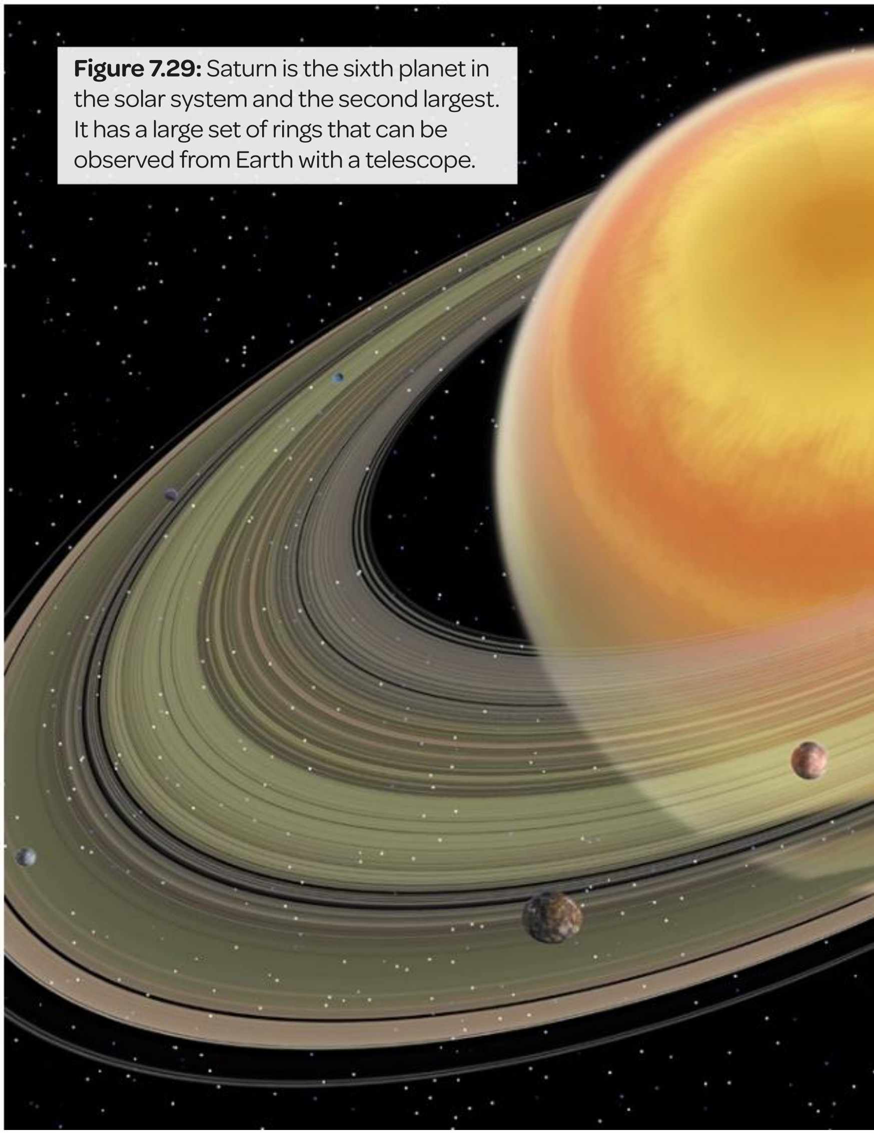


Figure 7.29: Saturn is the sixth planet in the solar system and the second largest. It has a large set of rings that can be observed from Earth with a telescope.

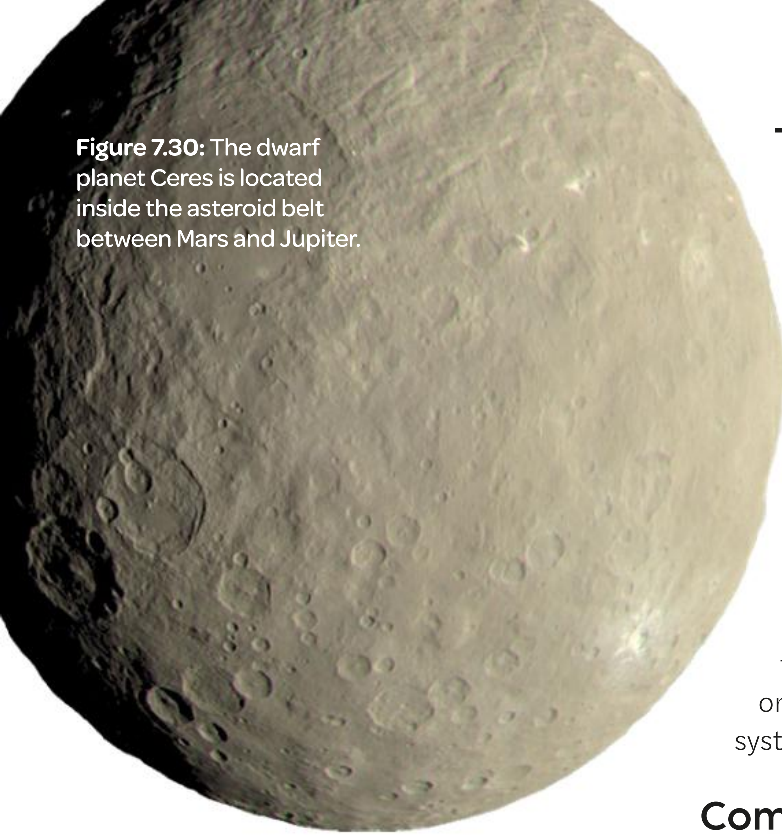


Figure 7.30: The dwarf planet Ceres is located inside the asteroid belt between Mars and Jupiter.

The asteroid belt and dwarf planets

In between Mars and Jupiter, we find the asteroid belt. Asteroids are irregularly shaped rocks that are thought to have been left over from the formation of the solar system. They vary in size from a few metres to a kilometre across. The dwarf planet Ceres, which is about half of the size of Earth's Moon, is also found in the asteroid belt. It is thought that Jupiter's gravitational field prevented the objects in the asteroid belt from forming into a planet.

A dwarf planet is a celestial object that orbits a star, is spherical, but is not large enough to have been able to clear its orbit. Pluto is one of the most famous dwarf planets. It has a very elliptical orbit that is on a tilt, which differs from other planets in our solar system. On average, it is about 39.5 AU from the Sun.

Comets, the Kuiper belt and the Oort cloud

Beyond the orbit of Neptune to about 50 AU from the Sun lies the Kuiper belt, a doughnut-shaped region of icy objects that is home to several dwarf planets, including Pluto. It is thought that the objects in the Kuiper belt are left over from the formation of the solar system.

Further out from the Kuiper belt is the Oort cloud. It is like a giant spherical bubble of ice, gas and dust that surrounds our solar system. The inner part of the Oort cloud is about 1000 AU from the Sun, and the outer part, and the edge of our solar system, is estimated to be about 100 000 AU from the Sun.

Comets are giant icy bodies that orbit the Sun. They originate from the Kuiper belt and the Oort cloud. As they come closer to the Sun, some of the comet starts to melt, appearing as a tail.

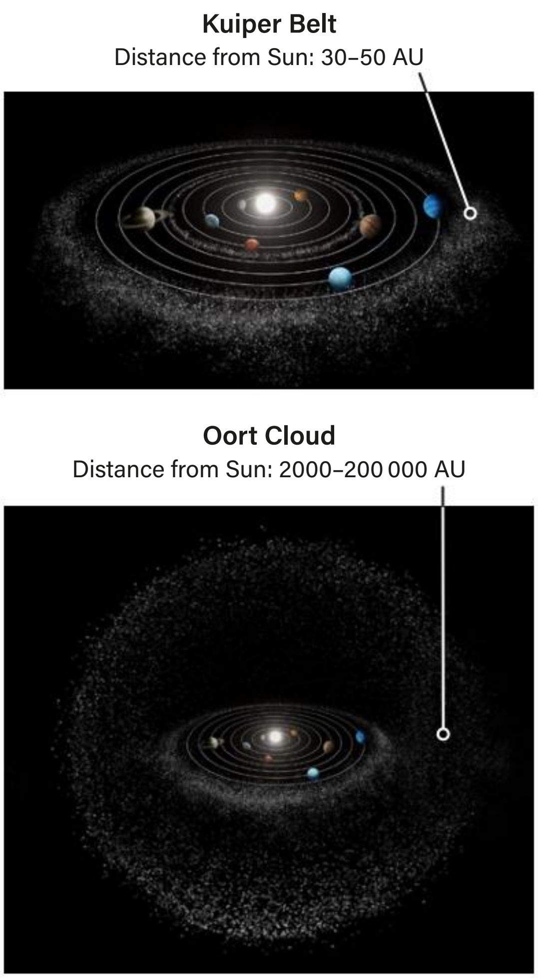


Figure 7.31: The Kuiper belt and Oort cloud are outer regions of our solar system filled with icy bodies left over from the formation of the solar system.

Figure 7.32: When comets move closer to the Sun, they begin to melt, releasing gas that creates their tail.

The Milky Way

A galaxy is a massive collection of stars, dust and gas held together due to **gravity**.

The Milky Way is a barred spiral galaxy about 100 000 ly in diameter. The arms of the galaxy orbit around a central point, thought to be a supermassive black hole.

Our solar system is located on the Orion arm about 25 000 ly from the centre. It takes about 250 million years for our Sun and solar system to make a complete orbit of the centre of the galaxy.

Figure 7.33: The Milky Way is a barred spiral galaxy. Our solar system is located about 25 000 ly from the centre.

Learning Ladder

Earth, the Sun and the Moon

1. Draw and label a diagram that shows the key features of our solar system.
2. Describe the key features of the rocky planets and the giant planets.
3. Explain why gravity is an important force in our solar system.
4. Compare the system of moons orbiting Jupiter with planets orbiting the Sun in our solar system.

Use and influence of science

1. Identify the answers below that illustrate a benefit of space exploration:
   A It helps us to develop new technologies.
   B It helps us to better understand our planet.
   C It helps us to understand our oceans.
   D It helps us to understand chemical reactions.
2. Select one of the benefits from Question 1 and describe how space exploration provides that benefit.
3. Space exploration costs billions of dollars. Conduct some research to find out about the amount that agencies such as NASA and the European Space Agency (ESA) spend on space exploration. Propose two points you could use in a debate supporting further investment in space technologies.

Evaluating

p. 239

Refer to Figure 7.28 and read through Investigation 7.9 on page 337 before answering the questions below.

1. Considering the scales that were used in Investigation 7.9, identify at least two errors in the scales used in the diagram of the planets in the solar system shown in Figure 7.28.
2. Describe one of the errors you have identified.
3. Use evidence from Investigation 7.9 to explain the importance of using scales in scientific models.
4. Discuss the value of images that are not to scale.
5. It has been claimed that producing a true scale model of the solar system on Earth is almost impossible. Evaluate this claim using what you know about scales of the solar system.

Success criteria

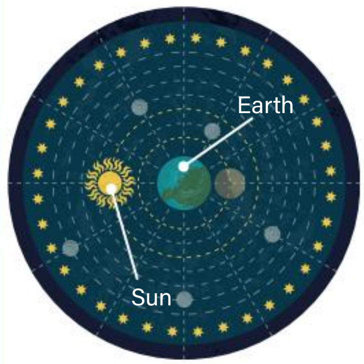
- I am able to describe key components of the solar system, including the planets, the asteroid belt and the Oort cloud.

Summary

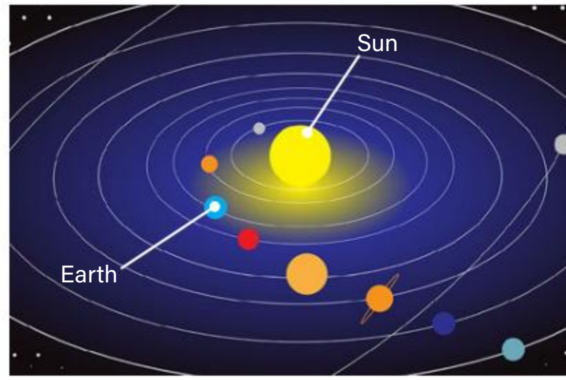
Earth's rotation on its axis causes day and night.

Models of the universe have developed over time as we have discovered new scientific evidence. The geocentric model of the universe (Earth at the centre) was replaced by the heliocentric model (Sun at the centre).

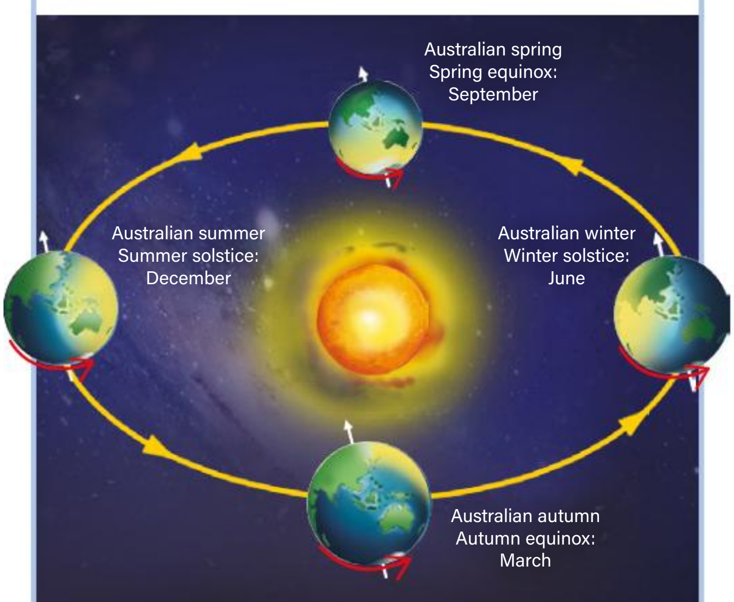
Geocentric model



Heliocentric model



Seasons are caused by the tilt of Earth's axis. This means that different countries have more or less direct sunlight depending on where Earth is in its revolution around the Sun.



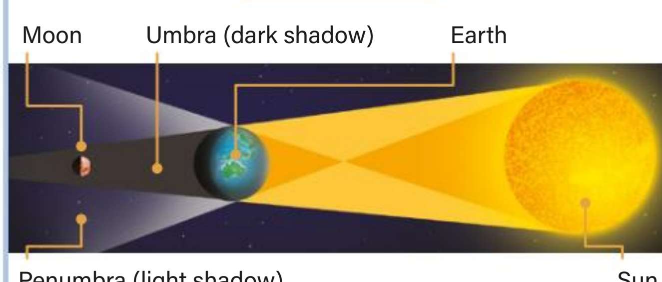
Equinoxes are when Earth experiences days and nights of equal length (12 hours each of daylight and of darkness). They happen in spring and autumn.

Solstices are when there is the greatest difference between the number of hours of daylight and of darkness. They happen in summer and winter.

Solar eclipse

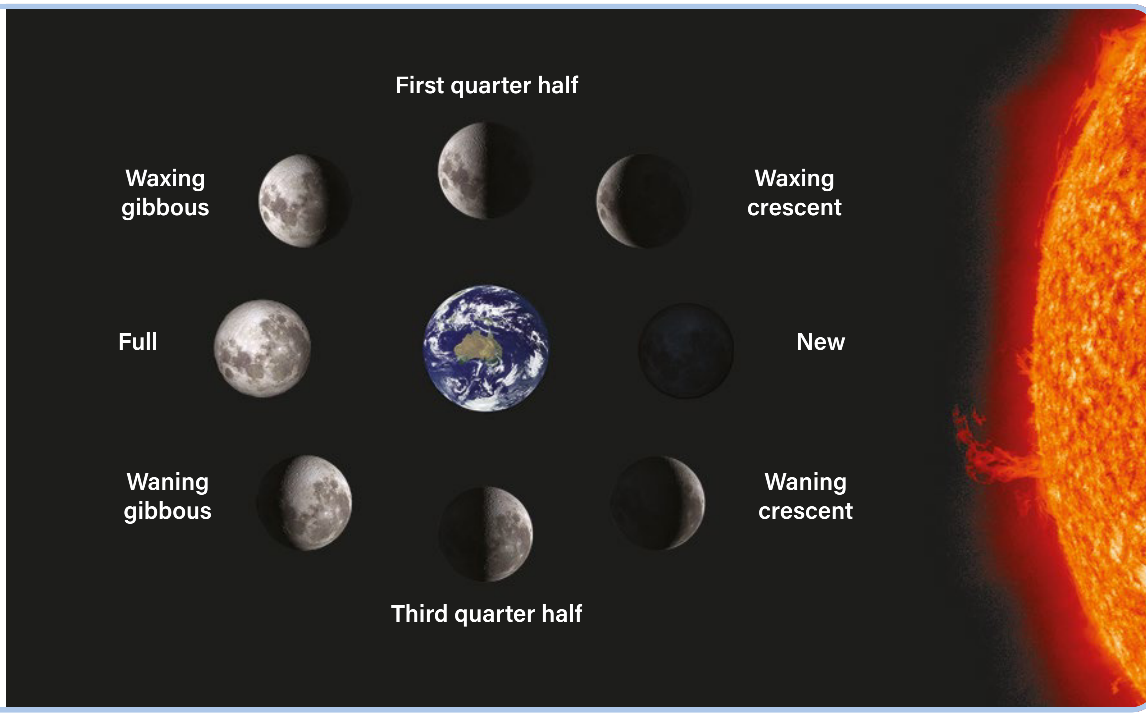
A solar eclipse occurs when the Moon blocks out the light of the Sun, casting a shadow over part of Earth.

Lunar eclipse

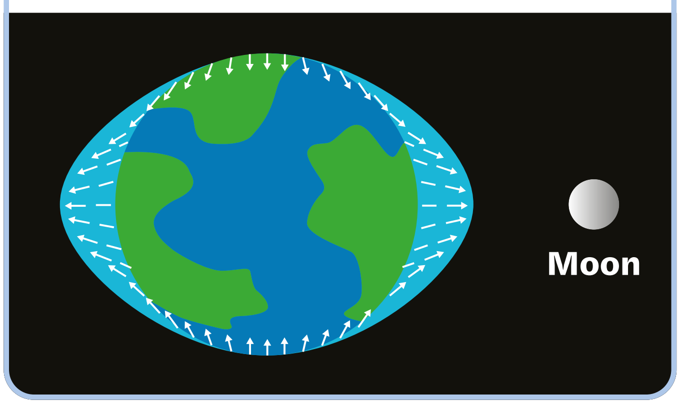


A lunar eclipse occurs when Earth blocks the light of the Sun, casting a shadow over the Moon.

Over a lunar month, the Moon cycles through different phases as the relative positions of Earth, the Moon and the Sun change.



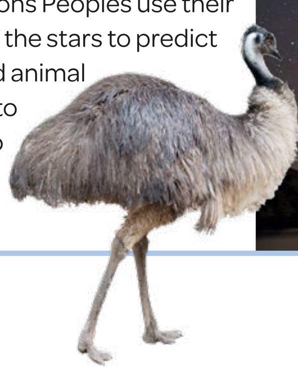
Tides are caused when the Moon's gravitational pull on Earth causes the water in the oceans to bulge out on the sides closest to and furthest from the Moon.



Technologies such as the James Webb Space Telescope have helped us to make discoveries about the universe.

Some First Nations Peoples use their observations of the phases of the Moon to understand, predict and use the ocean tides.

Some First Nations Peoples use their observations of the stars to predict the weather and animal behaviour, and to identify when to source various foods.



Key idea: Systems

Interactions in the Earth, Moon and Sun system are responsible for eclipses, tides and phases of the moon.

Our solar system consists of a star (the Sun), along with a group of planets and other objects bound together due to the gravitational force of the Sun.

Masterclass

Steps in progression

		1	2
Science understanding	**Earth, the Sun and the Moon**	Identify the three celestial bodies that interact during a solar eclipse.	Describe what you would experience if you were in the path of totality during a solar eclipse.
Science as a human endeavour	**Nature and development of science**	Identify the correct alignment of Earth, the Moon and the Sun during a solar eclipse: **A** Earth, Sun, Moon **B** Earth, Moon, Sun **C** Sun, Earth, Moon **D** Moon, Earth, Sun	Astronomers, meteorologists, geographers and cartographers collaborate to predict eclipses. Describe how collaboration across scientific disciplines helps to predict when and where a solar eclipse will occur.
Science as a human endeavour	**Use and influence of science**	Rewrite the statement below so that it is true. 'A solar eclipse can be viewed all around the world at the same time.'	Solar radiation during an eclipse can damage your eyes. Describe a way that your class could safely view an eclipse.
Science inquiry	**Questioning and predicting**	Rewrite the statement below so it is a scientific question: 'The distance between the Moon and Earth changes the type of eclipse.'	Use your knowledge to make a prediction that answers the question you identified in step 1.
Science inquiry	**Processing, modelling and analysing**	Use Figure 7.34 to identify the years when Australia will experience a solar eclipse.	Create a table to display the data shown in Figure 7.34. Include the date and states/territories impacted by the eclipse.
Science inquiry	**Evaluating** Creating a model of Earth, the Moon and the Sun can be useful for investigating eclipses.	Identify the scenario that contains an error when modelling eclipses. **A** Earth and the Moon are to scale. **B** There is no light source to create a shadow.	When creating a scale model of Earth and the Moon, students only have access to a rope with marks every 10 cm. Describe the type of error this could cause.

Chasing solar eclipses

Eclipses have always fascinated humans. Many ancient cultures have mythologies that explain them.

- In Norse mythology, solar eclipses occur when a wolf named Fenrir catches and eats the Sun, resulting in Ragnarok – a battle of the gods that would end the world.
- The ancient Chinese believed that solar and lunar eclipses were caused when the Sun or the Moon were eaten by a celestial dragon. The dragon could be scared away by loud bangs from drums or by fireworks.
- The ancient Greeks believed that a solar eclipse happened when the gods were angry, causing the Sun to abandon Earth.
- A Tahitian myth explains that the Sun and Moon are lovers, and cause eclipses when they join together.

Eclipses can be predicted using knowledge and measurements of the interactions between Earth, the Moon and the Sun. These measurements can be used to identify the time and date that the eclipse will occur, but also to plot a path on a map where people will be able to view the eclipse.

Demonstrate your understanding

3	4	5	
Construct a diagram or model to demonstrate how Earth, the Moon and the Sun interact to cause a solar eclipse.	Select one of the mythologies that explains eclipses. Compare it to the real cause of eclipses.	In many cultures, eclipses were thought to be a negative event. Discuss why these myths may have developed.	
Explain how being able to predict the time and location of an eclipse could improve scientific understanding.	Discuss how being able to view an eclipse from space could contribute to our scientific understanding of eclipses.	Analyse how eclipse data gathered from around the world could be useful in developing scientific understanding of eclipses.	
In the digital age, we can predict when and where solar eclipses will occur. Suggest how this ability impacts the way scientists share that information.	Discuss the impact that eclipse tourism could have on small, remote towns in Australia.	Propose how you would communicate information about an upcoming solar eclipse to your community. Justify your choices.	
Construct your own question about eclipses that you could investigate scientifically.	Use your knowledge to develop a hypothesis for the question you constructed in step 3.	Share your responses to steps 3 and 4 with a friend. Work together to evaluate your questions and predictions for scientific validity.	Science how-to p. 222
Use the data in your table to construct a graph that represents each state/territory and the number of eclipses.	Discuss any trends or patterns in the data represented in Figure 7.34.	Analyse the data from the graph in step 3 and justify any relationships and/or anomalies.	Science how-to p. 230
Students observe that total solar eclipses only happen when Earth, the Moon and the Sun are in a straight line in their model. Use your understanding of eclipses to explain this finding.	Discuss the following statement: 'Classroom models are not an effective way to learn about eclipses.' Use evidence to support your argument.	Some students claim that they can only model a lunar eclipse when the Sun is located between Earth and the Moon in their model. Evaluate their claim using evidence.	Science how-to p. 239

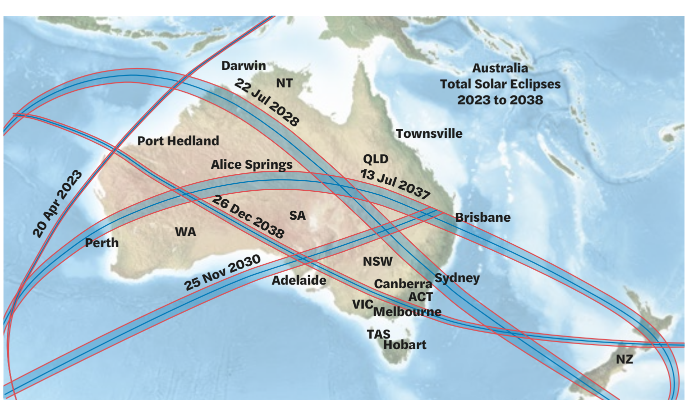


Figure 7.34: Australia will experience five solar eclipses between 2023 and 2038. The dark lines mark the path of totality, where people will be able to observe a total solar eclipse.

Eclipse chasers, or umbraphiles (shadow lovers), will travel around the world to experience a solar eclipse in different locations. It is very important not to look directly at the Sun during a solar eclipse, as the solar radiation can still damage your eyes. Instead, you can use special eclipse glasses, or indirect ways such as a pinhole camera or video, to view the eclipse.

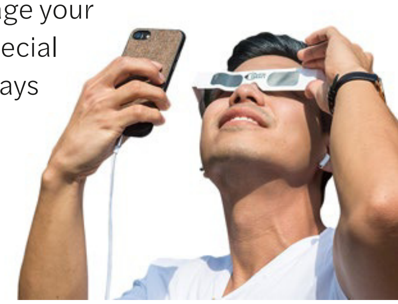


Figure 7.35: Using a phone and eclipse glasses to safely view a solar eclipse

8.0 Forces and simple machines

Forces are acting everywhere, all around us. They keep Earth in motion around the Sun, they help us to play different types of sports, and they make efficient transport possible in the air, on land and at sea. Forces are also acting on us all the time, pushing and pulling us in all directions. They bring us back to the ground after we jump in the air, and they help us to regain our balance when we slip. Our understanding of forces has also helped us to develop and operate machines and to use them to achieve incredible things, from constructing the pyramids in ancient Egypt to exploring other planets.

Figure 8.1: Forces keep planets and spacecraft in motion.

Learning Ladder

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

Steps in progression	Science understanding: Physical science: Forces and simple machines	Science as a human endeavour: Nature and development of science	Science as a human endeavour: Use and influence of science
5	I can analyse how simple machines alter the direction and magnitude of forces	I can analyse how people with different perspectives and worldviews collaborate to develop scientific knowledge	I can analyse how the communication of scientific knowledge shapes viewpoints, policies and regulations
4	I can predict how an object's motion is impacted when forces are applied	I can discuss how models and theories have developed over time	I can discuss the impact of responses to socio-scientific issues
3	I can represent and explain the effects of forces acting on objects	I can explain how new evidence can lead to changes in scientific knowledge	I can explain examples of ethical, environmental, social and/or economic impacts of scientific advances
2	I can describe how forces can be used for different purposes	I can describe the importance of multidisciplinary collaboration in science	I can describe how scientific knowledge can affect society
1	I can identify forces acting on objects	I can recognise scientific problems and solutions	I can identify socio-scientific issues

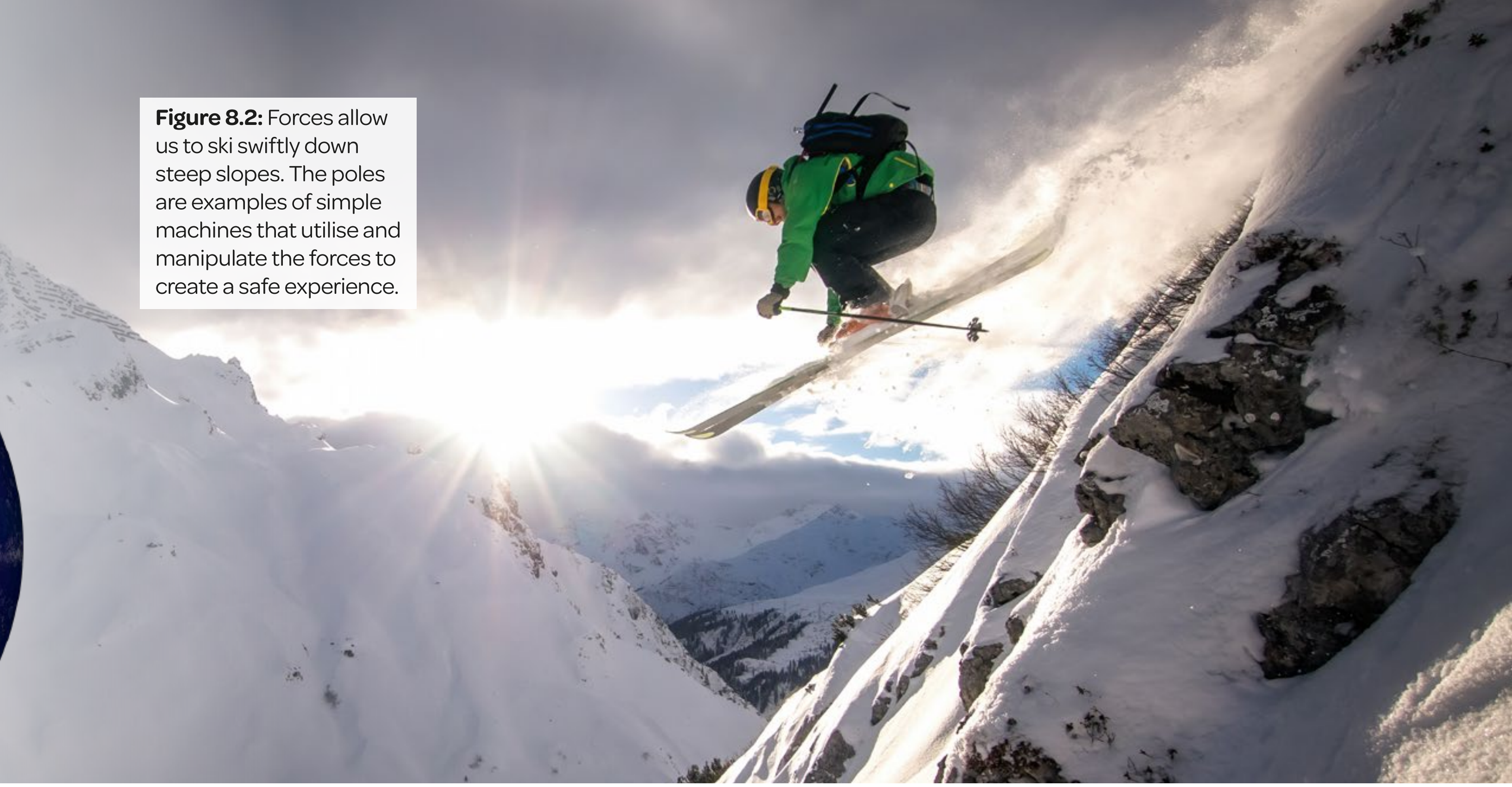


Figure 8.2: Forces allow us to ski swiftly down steep slopes. The poles are examples of simple machines that utilise and manipulate the forces to create a safe experience.

Science inquiry

Steps in progression	Questioning and predicting	Processing, modelling and analysing	Evaluating
5	I can evaluate investigation questions and predictions for scientific validity	I can analyse processed data for patterns, trends, relationships and anomalies	I can evaluate conclusions and claims with reference to conflicting evidence and unanswered questions
4	I can develop a hypothesis that predicts the relationship between investigation variables	I can identify and discuss trends and/or patterns in a range of dataset representations	I can create evidence-based arguments to justify conclusions or evaluate claims
3	I can construct questions and predictions to investigate scientific problems	I can process data by using mathematical relationships and/or constructing graphs	I can use science-based explanations to support investigation findings
2	I can make simple predictions based on what I know and observe	I can organise and display data using tables, keys and/or models	I can describe different types of errors in an investigation method
1	I can recognise questions that can be investigated scientifically	I can identify data from tables and graphs	I can identify errors and assumptions in an investigation

8·1 ▸ Direct and indirect forces

Learning intention

At the end of this lesson, I will be able to identify forces as either direct (contact) or indirect (non-contact).

Key terms

direct force: a force that acts on an object when in contact with another object; also known as contact force

field: an area of space where objects are affected by an indirect force

force: a push, pull or twist on an object when it interacts with another object

force diagram: a simplified diagram showing the direction and size of forces acting on an object

friction: a force between two surfaces that are sliding, or trying to slide, across each other

indirect force: a force that acts on an object without the need for physical contact; also known as non-contact force

interact: for objects to act upon or have an effect upon each other

newton (N): the unit for measuring force; SI unit N

tension: a pulling force exerted by each end of an object

Investigation 8.1

Push, pull or twist, p. 340

Key idea: Systems

Figure 8.3: A soccer ball is set in motion when kicked by a player.

A **force** is a push, a pull or a twist. Forces occur when objects **interact** with each other.

Forces happen when objects interact

A ball sitting on the ground will not move until a force is applied to it. If you apply a force by kicking the ball, several things happen.

- The ball changes shape for a moment.
- The ball moves in the direction of the force from the kick.
- The ball's speed changes. Initially, the ball is not moving, then it moves, hits the ground and stops, rolls or bounces.

Energy is required to apply a force. The person kicking needs energy to kick the ball. The energy is transferred to the ball at the same time as force is applied to it.

Direct forces are in contact

A **direct force** is when objects are in contact. For example, kicking a soccer ball is a direct force since there is physical contact between the foot and the ball. Direct forces are also known as contact forces and include:

- **friction**, when two objects slide past each other
- **tension**, a pulling force exerted by each end of an object such as a string or rope.

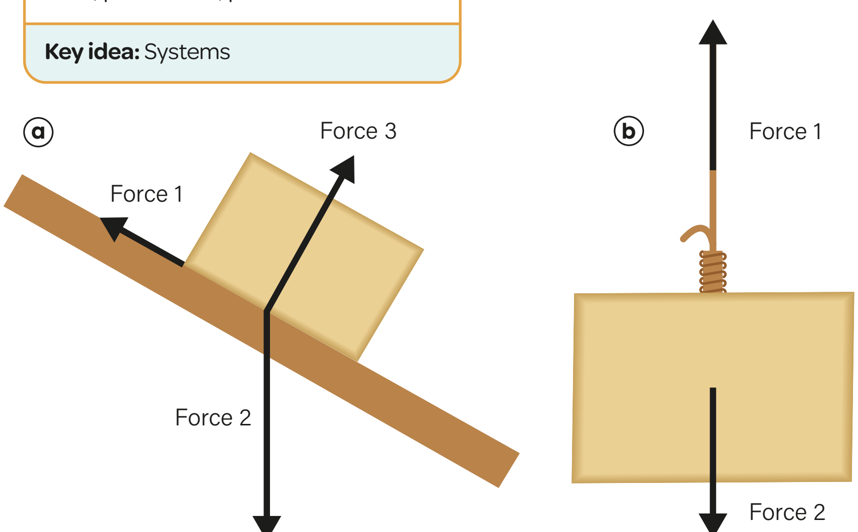


Figure 8.4: (a) Forces acting on an object moving down a ramp; (b) Forces acting on an object suspended by a rope

We use **force diagrams** like Figure 8.4 to show the forces acting on an object in a simple way. The arrows represent the size and direction of the forces. Longer arrows represent bigger forces. Force is measured in units called **newtons (N)**.

Indirect forces are not in contact

Some objects can exert forces on other objects, even if they are not touching them. These forces are called **indirect forces** and act through a **field** – an area around the object.

The three main types of indirect forces are gravitational, magnetic and electrostatic. For example, Earth exerts a pulling force of gravity on the Moon because the Moon is in its gravitational field. Gravitational forces will be explored in more depth later in this chapter.

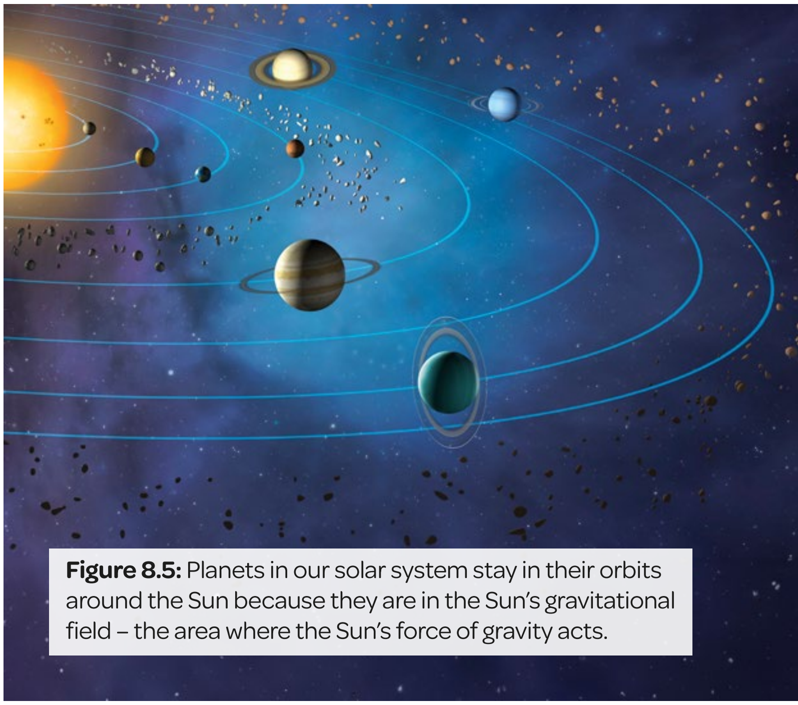


Figure 8.5: Planets in our solar system stay in their orbits around the Sun because they are in the Sun's gravitational field – the area where the Sun's force of gravity acts.

Learning Ladder

Forces and simple machines

1. Identify each of the following forces as a push, pull or twist.
   - **a** Opening a door towards you
   - **b** Moving your shopping trolley straight ahead
   - **c** Using a key to unlock a door
   - **d** Wringing out water from a wet towel
   - **e** Playing tug-of-war
2. Identify and give examples of three types of:
   - **a** direct forces.
   - **b** indirect forces.
3. Explain, in terms of forces, what happens when a magnet is brought close to a metal surface.

Nature and development of science

1. Forces can be difficult to understand. Propose how force diagrams help to address this problem.
2. Engineers and astronomers sometimes work together. Describe why this is important when forces are involved.
3. Gravity applies force on objects without direct contact. Propose how this might have encouraged scientists to learn more about indirect forces.
4. Describe how force diagrams model the forces experienced by objects. Discuss how these models have influenced people's understanding of forces.
5. Analyse and discuss the following statement: 'People in developing countries shouldn't be expected to contribute scientific developments'.

Processing, modelling and analysing *p. 230*

1. Copy and complete the table below based on your responses to Questions 1a to 1e opposite. Add rows for the other action forces.

Force	Push	Pull	Twist
Opening a door towards you			

2. You investigate which action to open a door requires the most force: push, pull or twist (door knob). You do three trials for each action and measure the force in newtons (N). Construct a blank table to collect data for this investigation. (*Hint:* Include a column for the average force.)
3. Construct a simple column graph to represent the 'could-be' data from Question 2. (See page 272 of the Science how-to section for how to create a column graph.)

Key idea: Systems

Figure 8.4(a) represents a simple system. Annotate this diagram with terms and detailed descriptions to explain the interaction between objects, as well as the forces involved in this system.

Success criteria

- I can identify whether forces are direct (contact) or indirect (non-contact).
- I can identify the features of a force diagram.

8·2 ▸ The direction and size of forces

Learning intention

At the end of this lesson, I will be able to identify characteristics of specific forces in terms of size and direction.

Key terms

applied force: a force that is applied to an object by a person or another object

magnitude: the size or power of an object, energy or force

mass: the amount of matter an object contains

net force: the sum of all forces acting on an object

Investigation 8.2

Balloon rockets, p. 341

Key idea: Systems

Every moment of the day, you are either applying forces to objects or having forces applied to you. Each force has two key characteristics: direction and magnitude (size). The direction of the force affects the direction that an object moves in, and whether it slows down or speeds up. The size of the force affects how much the object might move, or how quickly it speeds up or slows down. How big or heavy the object is also plays a role in how it responds to **applied forces**.

Every force acts in a certain direction

As you saw in Section 8.1, a force can be shown in a diagram as an arrow that points outwards from an object in the direction it is moving as a result of the force being applied to it.

Imagine that you and your family are at the supermarket and you are in charge of the shopping trolley. In what directions could you apply force? The direction of the applied force determines the direction in which an object will move. It can also determine if the object speeds up, slows down or changes direction.

Figure 8.6: The direction of the applied force determines the direction in which an object will move.

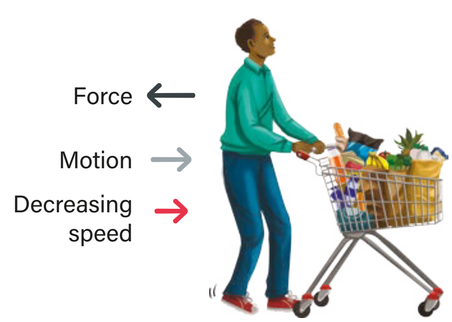
(a) You could push the trolley. This applies force in a forwards direction and makes the trolley move that way.

(b) You could pull the trolley to make it move backwards.

(c) You could try swinging the handle to the side to make it spin. The force is directed to the side of the trolley, but the motion is a turn, rather than a sideways push.

(d) If you started running while pushing the trolley ahead of you, you could keep pushing on it to make it go faster.

(e) The only way to stop the trolley quickly would be to apply a force in the opposite direction.



Every force has a magnitude (size)

A force can be strong or weak, great or small. As with direction, the **magnitude** (size) of the force is shown when drawing force diagrams. A larger arrow means a larger force. Recall that force is measured in newtons (N), and **net force** is the sum of all forces acting on an object.

After your family finishes at the supermarket, you head home and make dinner. Before you sit down to eat, you need to set the table. How much force should you apply when you shut the cutlery drawer? If you slam the cutlery drawer with a large force, it will close quickly. The drawer frame applies a force of the same size and opposite direction to stop the drawer. This is what causes the loud slamming noise.

If you close the drawer more gently (using a smaller force), it will take longer to close or may not close at all. The drawer frame applies a force of the same size and opposite direction to stop the drawer. Because the force is much smaller, there is no slamming sound.

The mass of an object affects how it responds to forces

The amount of matter that makes up an object – how big or heavy it is – is called its **mass**. Its mass will determine how an object's motion changes when forces are applied to it. A heavier object requires more force to move or stop it, compared to a lighter one.

For example, an empty shopping trolley is easy to push and quick to stop. However, a full trolley, which has more mass, needs more effort to start moving and more force to stop it. If you push two trolleys, one full and one empty, with the same magnitude of applied force and then let go of them, the empty trolley will travel further than the full one before coming to a stop.

Figure 8.7: An object's mass affects its response when forces are applied to it.

Learning Ladder

Forces and simple machines

1. Recall how the following are represented in a force diagram:
   a Direction. **b** Magnitude (size).

(For questions 2–4) Imagine you are pushing an empty shopping trolley when a child jumps in front of you.

2. Describe how you would use forces to avoid bumping into the child.
3. Construct two force diagrams to show the characteristic forces on:
   a you and your trolley just before the child appears.
   b the end result, where you stopped the trolley before bumping the child.
4. Predict how the characteristic forces would be different if your trolley were full but you still managed to stop it before colliding with the child.
5. Construct an infographic like Figure 8.6 to represent a variety of sport movements.

Use and influence of science

1. Propose a socio-scientific issue (economic, environmental, social, ethical) that could arise if it cost the same to post a small card as it did a large package (that is, objects of different mass).
2. Propose two realistic situations that a force diagram can help us to understand.

Questioning and predicting *p. 222*

1. Identify which of the following questions can be investigated scientifically. Provide a reason.
   A Why do bowling balls take so long to stop rolling?
   B How does the mass of a bowling ball affect how long it will roll after being pushed by a specific force?
2. Make a general prediction about whether heavier bowling balls will roll more or less than lighter bowling balls, when pushed with the same force.
3. Construct a scientific question to investigate how different-sized forces impact a certain object.

Key idea: Systems

Cars are complex systems that can speed up and slow down. Discuss factors that apply force in the forward and/or backward direction.

Success criteria

- I can describe how direction and size of forces impact motion.
- I can describe how mass affects the way an object responds to an applied force.

8·3 ▸ Balanced and unbalanced forces

Learning intention

At the end of this lesson, I will be able to describe forces as balanced or unbalanced, based on the motion of the object, and use force diagrams to model the forces acting on an object.

Key terms

balanced force: net force is equal to zero

normal force: the force that acts from a surface pushing against an object

resistive forces: forces that oppose the motion of an object)

stationary: not moving or changing position

thrust: the force that pushes an object forward

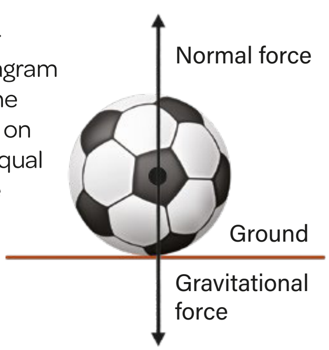
unbalanced force: net force is not equal to zero

Investigation 8.3

Blowball, p. 342

Key idea: Systems

Figure 8.8: ▸ This force diagram shows that the forces acting on the ball are equal in magnitude but opposite in direction, so they balance out.



An object can be acted on by many forces at once. If these forces are the same size but acting in opposite directions, then they are **balanced**. Objects acted upon by balanced forces stay at rest or move at a constant speed in one direction. If the forces acting are not the same size, then the forces are unbalanced.

A stationary object is affected by balanced forces

Even objects that are **stationary** (not moving) have forces acting on them. A ball at rest on the ground is not moving but it is still interacting with the ground. The ground pushes up on the ball with what is called **normal force**. The normal force is the same size as the force of gravity, but it acts in the opposite direction, so the ball does not move. The forces acting on the ball are balanced, so the ball remains stationary. When forces are balanced, the net force (overall force) acting on the object is zero.

Figure 8.8 shows a force diagram to model the forces acting on the ball. The arrows show that the force of gravity acts downwards, and the normal force (from the ground) acts upwards. The arrows are the same length, which means that the two forces are the same magnitude (size) and the ball is not moving up or down.

Forces can become unbalanced

If someone kicks the ball, the forces become **unbalanced**. This means the ball will start moving. When the size of the net force is greater than zero, the result is a change in speed or direction (or both) of the object (Figure 8.9).

▾ **Figure 8.9:** Balanced and unbalanced forces on a ball

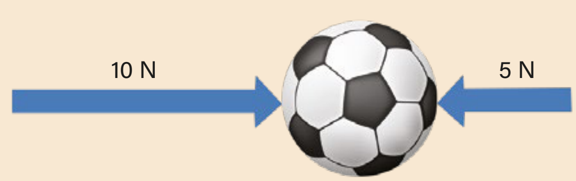
Balanced forces

Two forces are the same size but opposite in direction. They cancel each other out.

The net force is equal to 0 N.

Unbalanced forces

Two forces are different sizes and opposite in direction. They do not cancel each other out.



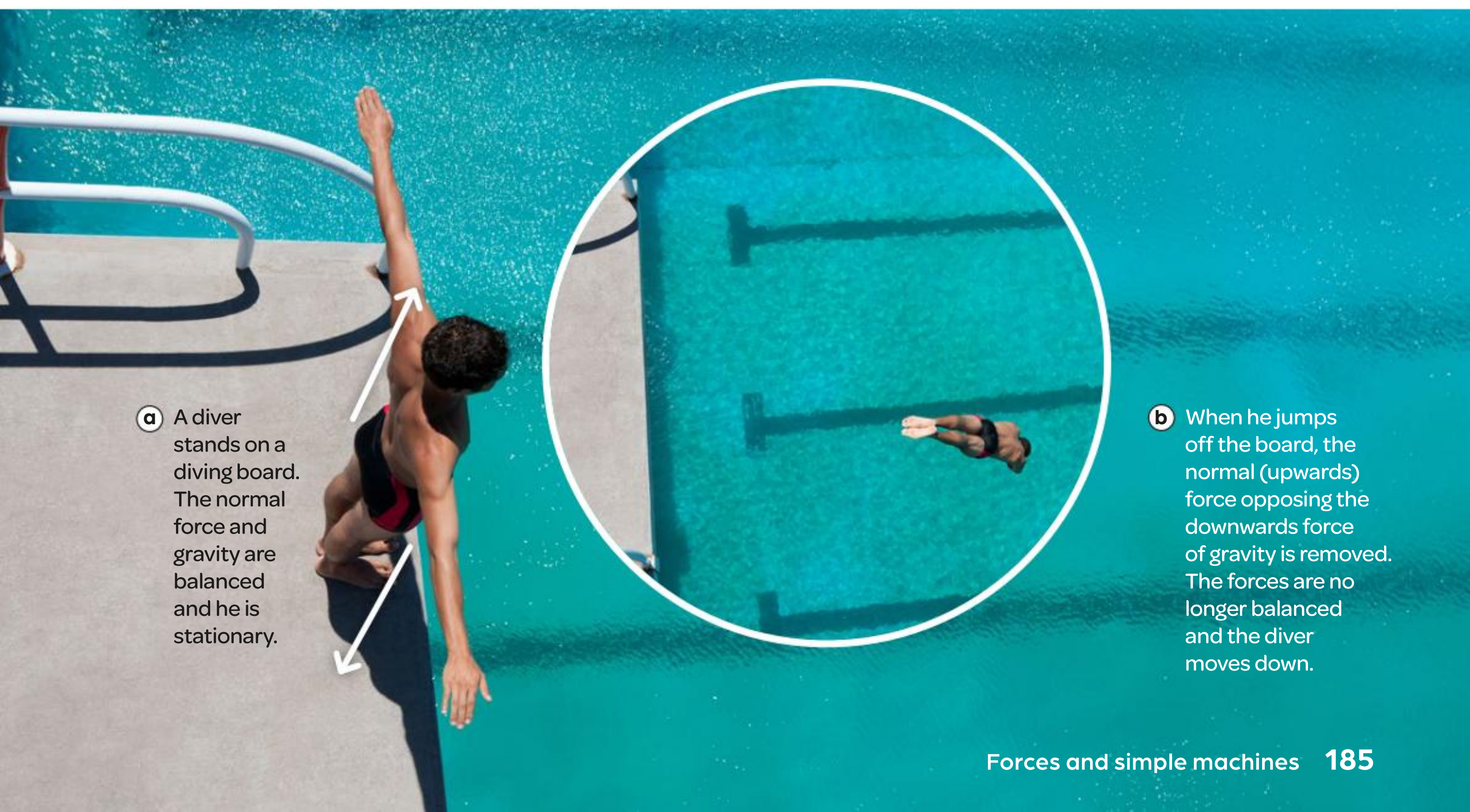
The force pushing the ball to the right is bigger than the force pushing to the left. The net force is equal to 5 N to the right.

Adding or removing a force can unbalance the forces on an object

The forces acting on objects, including humans, can become unbalanced by adding or removing forces. Examples of each are shown below.

Figure 8.10

Figure 8.11



A moving object might also be affected by balanced forces

When forces on an object are balanced, the object keeps doing what it has been doing. The object can be stationary or moving. When a car moves at a constant speed and direction, the forces acting on it are balanced. The **thrust** force from the car's engine is balanced by forces acting in the opposite direction (such as air resistance and friction). The normal force (pushing upwards from the ground) is balanced by the force of gravity (see Figure 8.12). Although the car is travelling quickly down the road, it is not changing speed because the forces are balanced and the net force is zero.

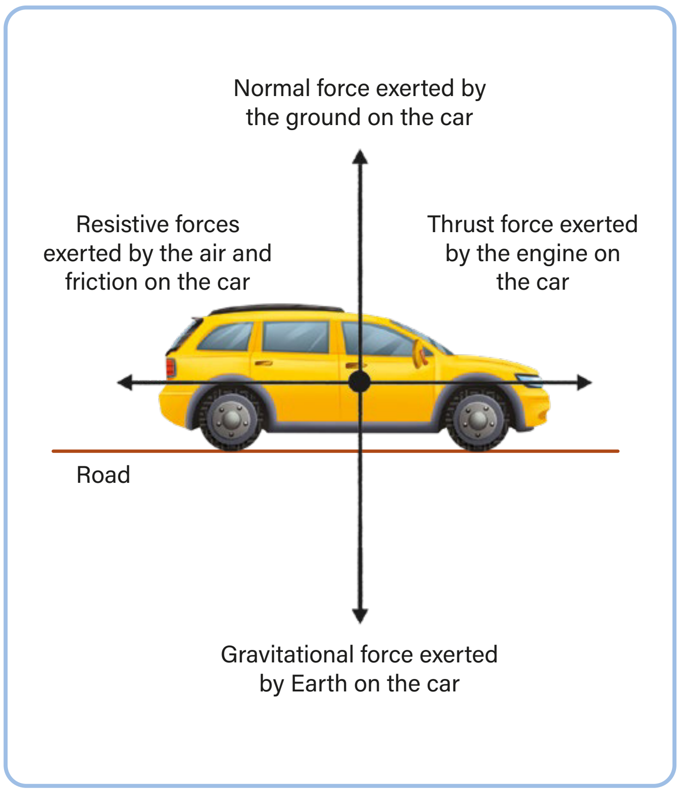


Figure 8.12: A force diagram of the balanced forces acting on a car moving at constant speed; net force = zero.

Forces can be added up to work out their effect

All forces acting on an object can be combined to determine the overall net force. Remember that net force is the force that is observed when all forces acting on an object are added together. Determining net force allows us to predict motion.

When the amount of the forces acting on an object are known, you can calculate the direction and size of the net force. Imagine a car that has broken down and two people are pushing it to the side of the road (see Figure 8.13). They are applying a force to the car to get it moving, and they need to have energy to apply the force. The forces acting on the car become unbalanced, and it starts to roll forward. You can work out the direction the car will move in, and the net force acting on it, as shown in Figure 8.13. The two people apply forces of 275 N and 395 N, to oppose the **resistive forces** of 560 N. To calculate the net force, add the pushing forces and subtract the resistive forces because they act in the opposite direction:

$$(275 + 395) - 560 =$$

$$670 - 560 =$$

$$= 110\text{ N}$$

So, the car moves to the right with a net force of 110 N.

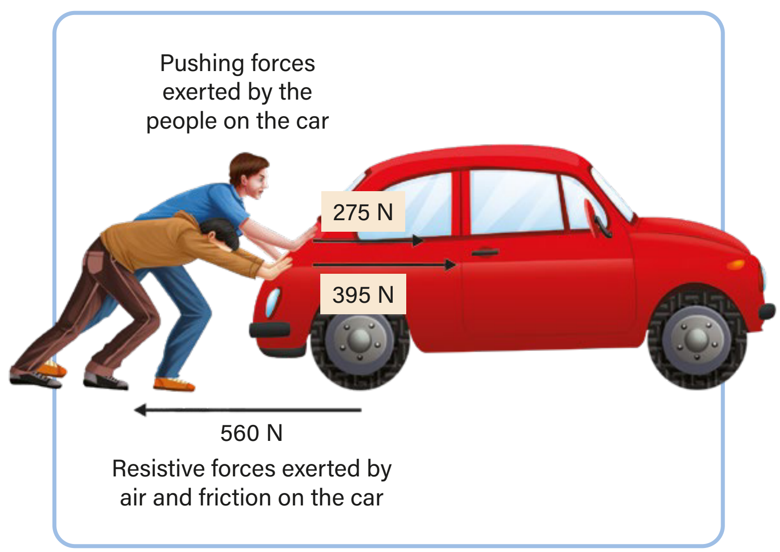


Figure 8.13: The magnitude of forces acting when pushing a stationary car

Learning Ladder

Forces and simple machines

1. Identify the force that:
   - **a** stops a person from falling through the ground.
   - **b** stops a person from floating off into space.
   - **c** slows a skateboarder down.
2. Describe two ways that unbalanced forces can change an object's motion.
3. Consider a stationary cyclist.
   - **a** Construct a force diagram of the forces acting on them.
   - **b** Explain two ways that the overall forces acting on them can become unbalanced.
   - **c** Adapt your force diagram in part **a** to show the forces in part **b**.
4. Construct a timeline to predict how an object's motion and position will be impacted when a force acts on it in the opposite direction to its motion.
5. Justify the predictions in your timeline from Question 4.

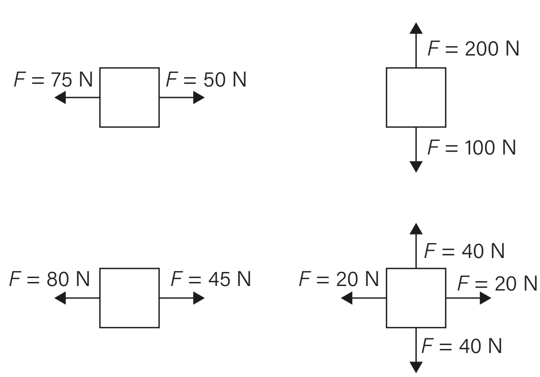
Use and influence of science

1. Friction is a force that resists motion. Propose whether this presents an economic, environmental, ethical or social issue for scientists. Provide a reason.
2. Propose how using science to determine how much fuel is required to launch a rocket into space has affected society.

Processing, modelling and analysing p. 230

1. **a** Label the types of forces acting on this girl.
   b Identify the direction of her motion based on the size of the force arrows.

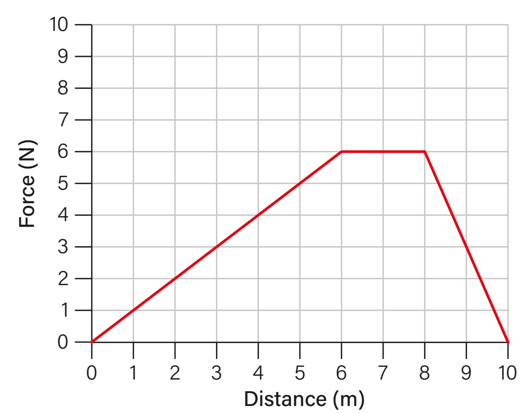
2. Calculate the net force acting on each of the following objects. State the direction of movement of the object.



3. Students conducted an experiment where they increased the mass of a cart and measured the force required to move the cart across a surface. Their results are shown in the table.

Mass (kg)	Net force (N)
1	5
3	15
5	25
7	35
10	50

   Construct a graph to visually display the relationship between mass and net force. Be sure to follow all of the scientific conventions. Refer to step 3, 'Processing, modelling and analysing', on page 232 in the Science how-to for assistance.
4. **a** Identify and describe the trend in the graph constructed in Question 3.
   b Explain the relationship between the variables observed in the graph.
5. A box was pushed across the floor in a straight line for 10 metres. The net force exerted over this distance is shown in the graph below.
   - **a** Identify the forces acting on the box as it moved across the floor.
   - **b** Deduce the greatest net force applied. Between which distances was it applied?



Key idea: Systems

With the aid of force diagrams, explain the forces acting on a skydiver during each stage of their motion: jumping out of the aeroplane, falling at a constant speed, opening the parachute, and then finally landing.

Success criteria

- I can describe balanced and unbalanced forces.
- I can construct force diagrams to show balanced and unbalanced forces and determine net force.
- I can predict the motion of an object based on net force.

8·4 ▸ Friction

Learning intention

At the end of this lesson, I will be able to describe friction as a type of force and explain how it impacts on an object's motion and produces heat.

Key terms

dissipate: remove or cause to disappear

friction: a force that resists the motion of an object

kinetic friction: a friction force that acts in the opposite direction to the motion of an object

incline: a surface with an upward slope

static friction: a friction force that keeps an object in place on a surface

Investigation 8.4

Heat from friction, p. 343

Key idea: Systems

Friction is a force that acts in the opposite direction to the motion of an object; it resists the motion of an object that is moving or stationary. Friction depends on the mass of an object and the types of surfaces involved.

Even if an object is not moving, a force of friction may be stopping it from slipping or sliding. 'Air resistance' and 'drag' are common names for the friction on objects as they interact with the air around them. The work of friction can convert energy into heat, which is often observed when objects are rubbed together.

Static friction prevents objects from moving

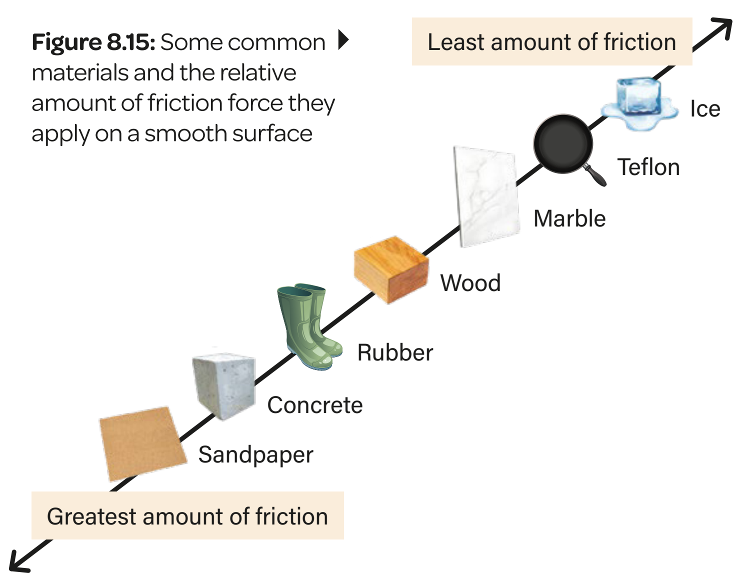
Objects do not have to be moving for friction to act upon them. **Static friction** can act on objects, keeping them in place on a surface. Any time you have taken a step without slipping, this was due to static friction. Imagine trying to run with no static friction. It would be like trying to run on ice! Your feet would slip out from under you with every step because they would not be able to get traction on the ground.

Static friction also applies to objects on an **incline**. You can stand on a ramp or slope without sliding down because the interaction between the slope and the soles of your shoes produces a friction force large enough to oppose the forces acting downhill.

If you are standing still and not sliding, like the woman shown in Figure 8.14, the static friction force must be equal to the downhill force. If the downhill force is greater than the maximum friction force of your shoe, you will begin to slip. This maximum depends on the materials of the slope and of your shoes. Figure 8.15 shows some common materials and the relative amount of friction force they apply on a smooth surface.

Figure 8.14: The downhill force on a slope depends on the normal force and the force due to gravity.

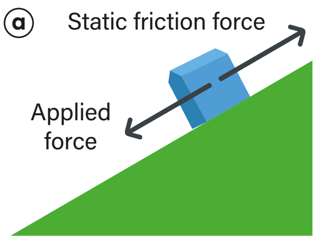
Figure 8.15: Some common materials and the relative amount of friction force they apply on a smooth surface



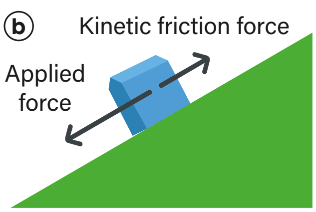
Kinetic friction makes moving objects slow down or stop

When an object starts to move or slide, friction is still there. Whatever the object is moving along or through – floor, water or air – **kinetic friction** force is acting on it. If you have ever ice-skated, or slid across a polished floor, you will know that kinetic friction forces can be pretty small, but you will stop sliding and come to a stop eventually, due to the continual action of kinetic friction. The static friction acting on an object to keep it still is more than the kinetic friction needed to keep it moving. If you were sliding a box down a ramp, more force is required to *get* it moving than to *keep* it moving.

Figure 8.16: Static and kinetic friction forces



- When the box is stationary, static friction force = applied force. The box will not slide until the applied force is more than the static friction force.



- When the box is already sliding down, the applied force only needs to overcome the kinetic friction force to continue sliding. The kinetic force is less than the static friction force. It depends on the speed of the object and the material of the surfaces in contact.

Heat is a product of friction

Place your hands together, apply a little bit of pressure and then quickly rub them back and forth. Can you feel the heat? It is caused by the friction between the particles of your hands as they rub against each other. When a space shuttle re-enters Earth's atmosphere, heat friction can be generated at high speeds because of the high number of collisions between particles in the air and the shuttle. The air gets hot enough to form a glowing, fiery cloud around the shuttle.

Heat generated by friction can be **dissipated** in various ways. One common method is transferring heat from the hot object to cooler surroundings by direct contact. Cooling systems like fans and heat sinks help to dissipate heat by increasing the surface area for heat to be lost to the air. Additionally, lubricants and cooling fluids can reduce friction and carry away excess heat.

Learning Ladder

Forces and simple machines

1. Classify the following actions as utilising forces that are static friction or kinetic friction:
   - **a** Skiing down a mountain
   - **b** Using a travelator to get your trolley up a level
   - **c** Applying the brakes as you approach a red light
2. Identify differences between the soles of sneakers and of school shoes. Propose which provides more friction.
3. Describe how to increase the friction between your feet and the surface they are on now. Construct a diagram to represent the friction force.
4. **a** Explain how a car travelling at a constant speed experiences friction, but does not slow down.
   b Predict how its motion would change if the road surface suddenly became more slippery.
5. Justify your response to Question 4b in relation to direction and magnitude of forces.

Nature and development of science

1. Match a socio-scientific issue with each of the following:
   - **a** Using more salt on icy roads to increase friction
   - **b** Using cheaper rubber with less friction on shoes
   - **c** Adding a spoiler on the back of your car which increases drag but looks really cool
2. **a** Explain your responses in Question 1.
   b Propose at least two fields of science that could collaborate to address each issue.

Evaluating p. 239

Imagine you are doing an investigation to determine the minimum mass a block must be in order to slide down a ramp without pushing it. You have four different blocks that weigh 100 g, 200 g, 300 g and 400 g. If the 400 g block still does not slide, you will stack the blocks to further increase the mass to 500 g, 600 g, 700 g.

1. **a** Identify an assumption you are making about the blocks used in the investigation.
   b Identify two sources of error in the method.
2. Identify each error in Question 1b as random or systematic. Provide a reason for your response.

Key idea: Systems

Mechanical systems use special materials to minimise the friction between moving parts. Describe components used in industry that contribute to and minimise friction forces, and explain why this is done.

Success criteria

- I can explain the difference between kinetic and static friction forces and how they produce heat.

8.5 ▸ Factors affecting friction

Learning intention

At the end of this lesson I will be able to investigate factors that influence the size and effect of frictional forces.

Key terms

coefficient of friction: a value that indicates how easily an object moves when interacting with another material

lubrication: a substance that makes a surface slippery or smooth

Investigation 8.5

Friction of materials, p. 344

Key idea: Systems

Table 8.1: Friction coefficients of common metals

Metal on metal	Average friction coefficient (μ)	
	Clean and dry	Lubricated with grease
Aluminium	1.2	0.3
Copper	1.6	0.4
Steel	0.6	0.1
Silver	1.4	0.6
Cast iron	1.1	0.5

Friction is an essential part of movement. It is always there when objects start, stop and continue moving. The moving parts of machines and vehicles, such as engines and tyres, are carefully designed to minimise or make the best use of this force.

Different materials apply different amounts of friction

Why are the bottoms of your sports shoes not made out of metal? They would be much more durable and easier to clean. It would also be very hard to get traction when running in them – but why? Rubber, even without shoe patterns, is far less slippery than a sheet of metal. This is because of how the particles of the materials interact. A material's **coefficient of friction** is a measure of how easily an object moves when interacting with another material. Rubber has a high coefficient of friction, so rubber soles grip the ground strongly and get more traction than other materials. Metals have a low coefficient of friction, so they do not get as much traction on the ground. This makes metals the right materials for ice skates, which need to glide rather than grip.

You can place water, oil or grease between two surfaces to reduce the friction between them. This **lubrication** means that the surfaces are interacting with the slippery material of the lubricant rather than with each other. Figure 8.17 shows a layer of carbon used as a lubricant in an artificial hip joint to reduce friction.

Table 8.1 shows some common metals and their average friction coefficients, with and without lubrication.

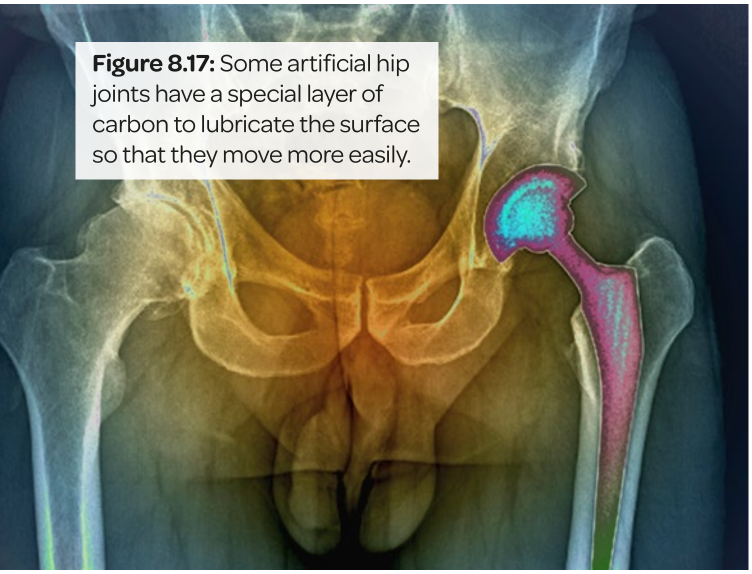


Figure 8.17: Some artificial hip joints have a special layer of carbon to lubricate the surface so that they move more easily.

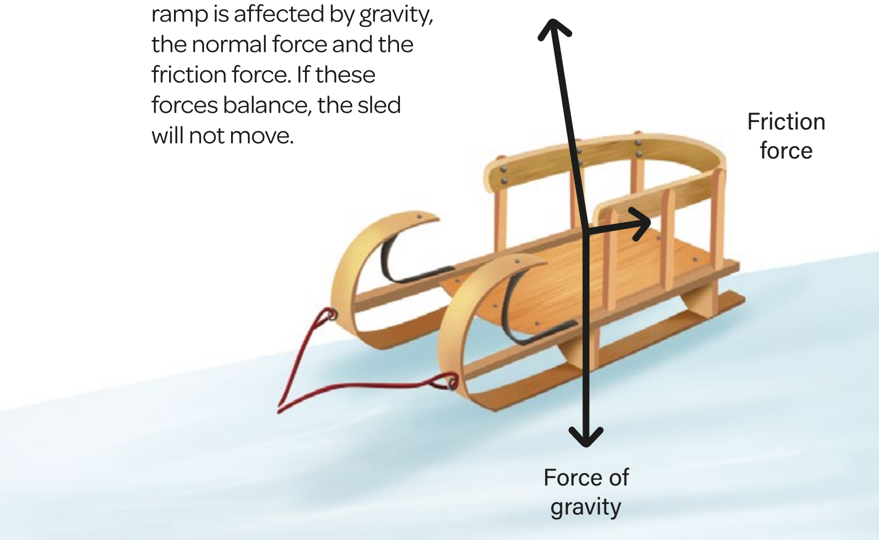
Figure 8.18: Meteorites will burn up in Earth's atmosphere due to the heat generated by friction with air particles.

Other forces in an interaction can change a friction force

Imagine you are packing equipment into a sled on a ramp. Which do you think would be more likely to slide away: a sled with a little equipment on it, or a fully packed sled? The fully packed sled would be more likely to slide off. This is because friction is due to the material's coefficient of friction and how much the objects are being pushed together by other forces.

At the start of this chapter, you learnt about the forces acting on a stationary object. A book on a table is pulled down by gravitational forces, but it stays in place because the normal force applied by the table pushes it back up. Figure 8.19 shows how that friction force keeps a stationary sled in balance.

Figure 8.19: A sled on a ramp is affected by gravity, the normal force and the friction force. If these forces balance, the sled will not move.



If you loaded the sled with more equipment, the force of gravity and the normal force would increase. This means the friction force would also increase to keep the sled still. But there is an upper limit to the friction force, depending on the materials of the sled and the ramp. Eventually, the friction force would not be strong enough to balance the other forces and the sled would slide away.

Let's look at this another way: how do you use your brakes when riding a bike? When you need to slow down or stop quickly, what do you do with the brakes? You apply a larger force on them. Why? You do this because the larger force applies more friction on your wheels from the brake pads, causing the bike to slow down more quickly.

Learning Ladder

Forces and simple machines

1. Identify four examples of forces from this section that display kinetic friction or static friction.
2. Refer to Table 8.1. Propose, and give a reason for your response, which material would be most suitable for creating an exercise device to increase:
   a strength. **b** agility (speed).
3. Explain why people need to drive more carefully when it is raining. Construct force diagrams to support your response.
4. Discuss how you can reduce the friction between the surfaces of two materials. Provide an example.
5. Justify the importance of reducing friction in machines with reference to an example.

Nature and development of science

1. Propose two ways that friction can cause problems, and two ways that it can solve problems.
2. Identify three items mentioned in this section that have impacted society for the better. Propose which branches of science may have contributed to their development.
3. Describe how friction science has contributed to technological advances such as artificial joints.

Questioning and predicting p. 222

1. Which of the following questions can be investigated scientifically?
   A How does the friction coefficient of a material affect a block's ability to slide down a ramp?
   B What are the friction coefficients of wood, metal and plastic?
   C Does outer space affect the friction coefficient of materials?
2. Predict the order of increasing friction of the following surfaces when wet: tiles, concrete, carpet, hardwood.
3. Construct a scientific question to investigate your prediction in Question 2.

Key idea: Systems

In the sport of curling, a large stone is pushed down an icy track while players use brooms to manipulate the friction between the ice and the stone to speed it up or slow it down. Research and discuss another activity that involves manipulating friction. Explain the components, factors and interactions of the system.

Success criteria

- I can describe how certain factors affect friction.

8.6 ▸ Gravitational forces

Figure 8.20: This astronaut is floating in space, outside Earth's gravitational field.

Learning intention

At the end of this lesson, I will be able to describe the motion of objects in a gravitational field, using the concept of forces, and distinguish between 'mass' and 'weight'.

Key term

gravity: the force of attraction between two objects

mass: the amount of matter an object contains

orbit: the path of an object around a star or planet (e.g. Earth around the Sun)

satellite: an object that orbits a planet; Earth has a natural satellite called the Moon plus many purpose-built artificial satellites

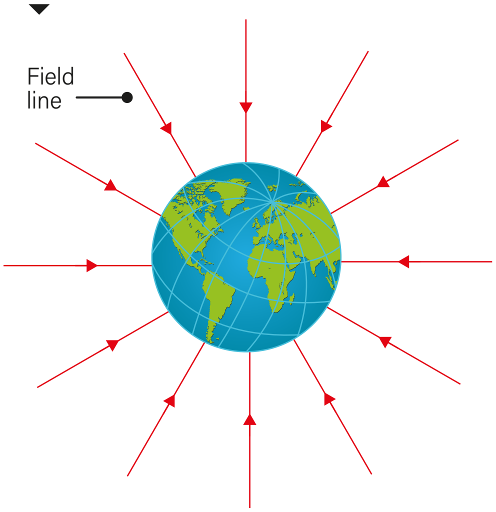
weight: the force of a gravitational field on the mass of a body

Investigation 8.6

Measuring gravity, p. 345

Key idea: Systems

Figure 8.21: Earth's gravitational forces. The field lines point towards Earth. The force of gravity is stronger the closer you are to Earth.



Gravitational forces act towards the centre of the object that produces them. That is why all objects, wherever they are, fall towards Earth's centre. And although people talk about 'weight' in terms of grams and kilograms, these are actually units of mass. But what is the difference? We will start by learning about gravity.

Gravity is always an attractive force

All objects with mass make a gravitational field. Within this field, any other object will have a force generated on it. The size of this force depends on the:

- mass of the object generating the force
- distance between the two objects.

The size of gravitational force varies, but the direction does not. Any force that is due to gravity will always be an attractive force. This means that it pulls objects towards the centre of the mass that is generating the gravitational field.

Wherever you are on Earth, if you drop something, it falls to the ground because it is attracted to the centre of Earth's mass (the centre of Earth). We are affected by Earth more than any other object because it is the largest and nearest object to us. The Sun is much larger, but it is so far away that its gravitational field has little effect on an object that is dropped, compared to Earth's gravity.

You can draw field lines to represent the area where gravitational force will be generated on an object:

- Stronger fields are shown with field lines close together; weaker fields are shown with field lines further apart.
- Gravitational field lines point in the direction in which the force is acting.

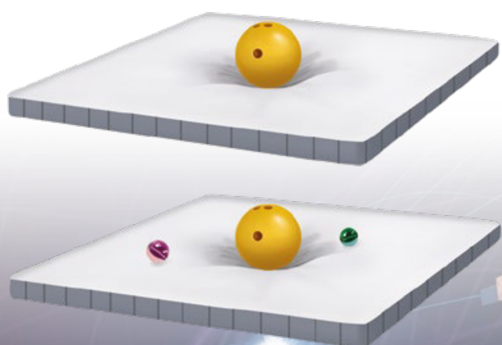
The closer an object is to Earth's surface, the stronger the gravitational field, as shown in Figure 8.21. The red field lines are closer together near Earth and further apart away from Earth.

Gravitational forces change with distance

On Earth's surface, gravity is constant because the distance from the centre of Earth is about the same everywhere. Further away from Earth, the gravitational force is smaller, represented by the field lines being further apart.

Imagine a soft mattress with a bowling ball placed in the centre, making a hollow. If you place some marbles at different points around the mattress, eventually they will all roll into the hollow made by the bowling ball. Those at the very edges may roll slowly at first, but they will roll faster as they get closer to the bowling ball, where the slope becomes steeper. This is very similar to the way that objects are affected by Earth's gravity: the force increases as the objects move nearer.

Figure 8.22: Gravitational fields can be modelled by a bowling ball on a mattress. The greater the mass of the object, the stronger the attractive force will be on objects that are nearby, like marbles rolling towards the bowling ball on a soft mattress.



Gravity holds objects in orbit

Gravity is the force that holds the planets in orbit around the Sun and satellites in **orbit** around Earth. The closer a planet is to the Sun, the stronger the Sun's gravitational pull on it and the faster the planet moves in its orbit. The further it is from the Sun, the weaker the Sun's gravitational pull on it and the slower it moves. Table 8.2 shows how long each planet takes to orbit the Sun.

Table 8.2: The number of Earth days taken by each of the planets to orbit the Sun, in order of closest to furthest away

Planet	Number of Earth days
Mercury	88
Venus	225
Earth	365
Mars	687
Jupiter	4331
Saturn	10 747
Uranus	30 589
Neptune	59 800

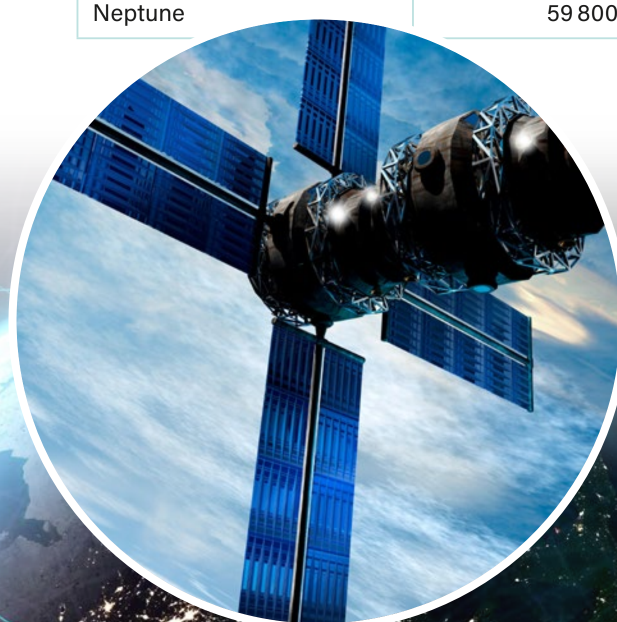


Figure 8.23: Many satellites orbit Earth. Satellites have many uses, such as communication, weather forecasting and navigation.

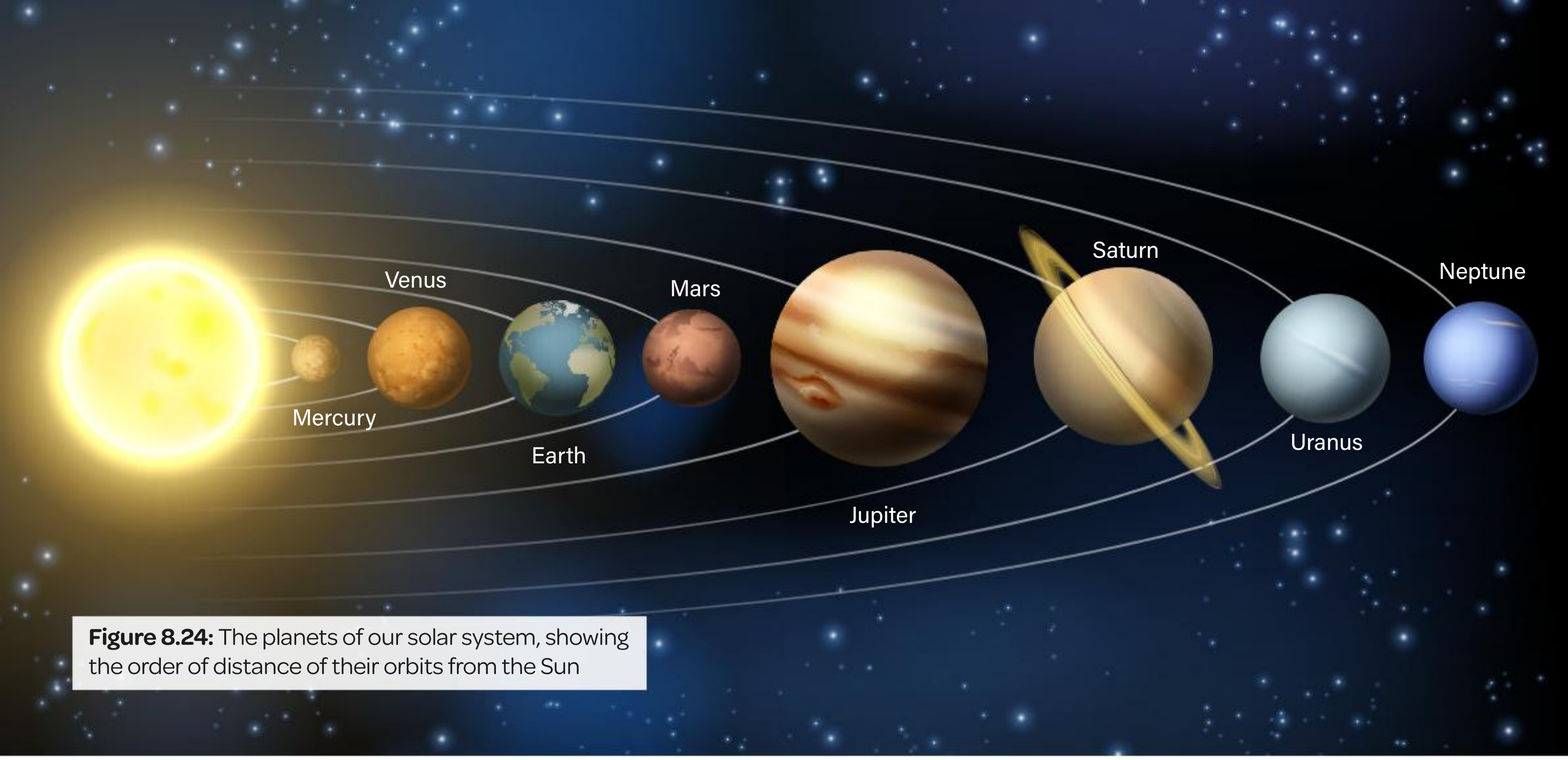


Figure 8.24: The planets of our solar system, showing the order of distance of their orbits from the Sun

You might wonder why gravity does not cause a planet to crash into the Sun. The Sun's gravitational force constantly pulls the planets towards it. However, the planets are travelling fast enough to balance the gravitational effect. This delicate balance causes the elliptical orbits of planets around the Sun, which is the centre of gravity for our solar system.

Satellites can orbit planets, in the same way that planets can orbit the Sun. The only difference is the central object being orbited. Earth is the central object, and the centre of gravity, for satellites orbiting our planet. The distance at which the satellites orbit from the surface of Earth depends on how fast they travel.

An object's weight depends on gravity

An object's **mass** is the amount of matter it contains. A ball contains a specific amount of matter. Wherever that ball is, even if it is on the Moon, its mass does not change. Mass is measured in grams (g) and kilograms (kg).

An object's **weight** is a measurement of how much gravitational force is pulling on it. Weight is measured in newtons (N). Changing the gravitational force acting on an object will change its weight.

The Moon exerts a small gravitational force compared to Earth, which is why astronauts on the Moon weigh less and can move around with huge jumps. It is also why astronauts on the International Space Station float, even though their bodies still have mass.

Figure 8.25: No matter where you are, your mass stays the same. However, your weight changes depending on gravity.

Figure 8.26: Astronaut Eileen Collins, weightless and floating in *STS-114* ISS Commander Space Shuttle Mission

Learning Ladder

Forces and simple machines

1 a Identify the force that pulls you towards the ground.
b Gravity is an __________ force that causes objects to __________ in a direction __________ the centre of the Earth.

2 Describe what 'gravity' means and explain what its strength depends on.

3 Explain how an object's weight can change even if its mass stays the same.

4 Imagine you throw a rock straight up in the air above your head. Outline the motion of the rock and the forces acting on it, from the moment it leaves your hands until its motion stops (on the ground).

Use and influence of science

1 Make a list of 10 inventions or useful things that the science of gravity has helped develop over time.

2 Select two things from your list in Question 1. For each, describe how life would be different today if they had not been invented.

3 a Describe the ways in which exploring the universe has contributed to our greater understanding of gravity.
b Describe an ethical or social implication of space exploration.

4 The notion of gravity has changed significantly over time, from the ideas of Greek philosophers, to Galileo, then to Isaac Newton and Albert Einstein. Use the internet to identify the social impacts of each progressive understanding of gravity and related phenomena.

5 Analyse how the development of our understanding of gravity has shaped viewpoints or policies and regulations.

Processing, modelling and analysing *p. 230*

Refer to Table 8.2.

1 a Identify how many Earth days it takes for Mars to orbit the Sun.
b Calculate how long this would be when measured in seconds. (See the Science how-to section on page 262 if you need help.)

2 One day on Venus lasts approximately 243 Earth days. Using Table 8.2, construct a new table that shows how many 'Venus days' it takes planets to orbit the Sun. (*Hint:* Divide the current number of days by 243.)

3 Construct a graph to display the information in Table 8.2. (See the Science how-to section on page 270.)

4 a Identify and discuss the trends shown in your graph.
b Convert the data from your table in Question 2 into a pie chart that shows the difference in time between the planets' orbits around the Sun. (See the Science how-to section on page 273.)

5 Compare the trends and patterns you identified in Question 4a to those you observed in your pie chart and analyse the differences.

Key idea: Systems

Drones, rockets, space shuttles and aeroplanes are systems that generate an upward thrust in order to lift off the ground. Choose one example to research and describe the mechanism the system uses to move against the force of gravity. Outline any positives and any negatives of your chosen method of lift-off.

Success criteria

- I can describe how objects are affected by gravitational forces.
- I can explain the difference between 'weight' and 'mass'.

8.7 ▸ Reducing the impact of forces

Learning intention

At the end of this lesson, I will be able to describe some examples of technological developments that have contributed to finding solutions to reduce the impact of forces in everyday life.

Key terms

deform: to change shape

impact: the effect of a force

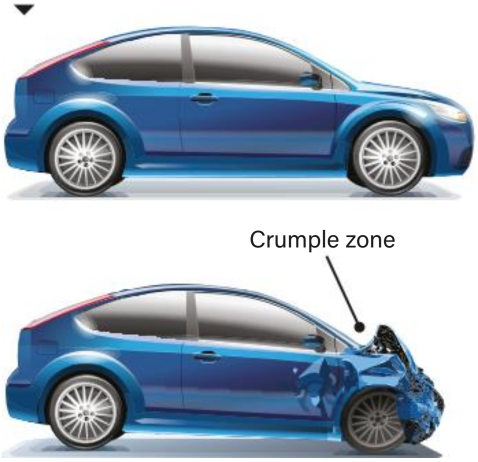
Investigation 8.7

Crash cushions, p. 346

Key idea: Systems

Figure 8.27: Well-designed shoes absorb impact.

Figure 8.28: The front and back sections of modern cars act as crumple zones if there is a collision.



Many activities involve forces that can be uncomfortable, painful or even harmful. Engineers and scientists have developed products that can reduce the **impact** of these forces. These products decrease the forces we feel by absorbing them or spreading them over a larger area.

Shoes can reduce forces on your feet

Most footwear has a sole made out of some combination of rubber, foam or other synthetic material. The design of these soles is meant to:

- provide grip, or traction, on a variety of surfaces
- reduce the force of impact from contact with a variety of surfaces.

When you step on a pointy rock wearing shoes, the sole briefly changes its shape – it **deforms** around the rock, spreading the contact force over a greater area. When you are walking or running, the impact of the ground can be evenly spread out across your foot if your shoes are designed well and fit you properly.

Crumple zones absorb some impact in car accidents

Vehicles let us travel much faster than we can on our own. This increased speed comes with more risk. Why would you rather bump into a wall while walking than when running? It is because the forces you experience are much greater at higher speeds than at lower ones.

If a modern car crashes into another object, its design means it will deform. This reduces the forces on the driver and any passengers. The front and rear of the car each have an area that is designed to deform during a collision. This area is called a crumple zone.

How do crumple zones protect us? Think of it like running into a wall, but this time you are holding a cardboard box in front of you. The box will be crushed first, absorbing some of the impact before it reaches you.

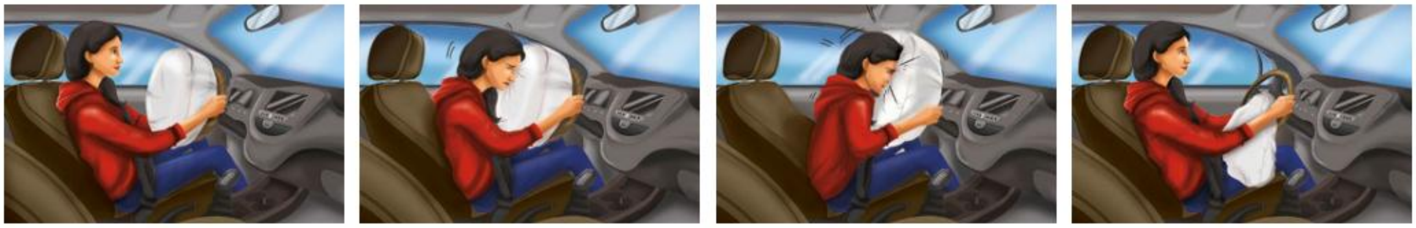
The longer a collision lasts, the less damage it will do. Therefore, almost all safety equipment, like crumple zones, helmets and padding, are designed to maximise the amount of time a collision takes, and to absorb as much of the impact as possible.

Airbags absorb impact for individual car passengers

Almost all modern cars have airbags built into surfaces. Airbags work in a similar way to crumple zones, but instead of providing overall protection for people inside the vehicle, they protect the individual passengers in particular ways.

The principle of an airbag is the same as with other safety equipment. It maximises the duration of impact, and so reduces the maximum force by spreading it out over more time (Figure 8.29). The passenger endures a force that is less than if there were no airbag.

Figure 8.29: The effect of an airbag on the force caused by a collision



1. The bag inflates upon collision.
2. The passenger keeps moving forward until they make contact with the airbag.
3. The airbag slows the passenger's movement and begins to deflate upon contact.
4. The passenger slows to a stop, but takes longer to do so because of the airbag.

Learning Ladder

Forces and simple machines

1. Identify the type of force (push, pull, twist, friction) displayed by each of the following items/actions:
   a Outside layer of our shoes **b** Inside padding of shoes
   c Crumple zone **d** Using a spanner
   e Removing your phone charger from the outlet
2. Describe another benefit a shoe's sole provides the wearer, other than grip or traction.
3. Explain how the sole of a shoe, and the crumple zones and airbags of a car, all behave in response to forces. Use diagrams to support your response.
4. True or false: *A collision involving a cyclist or motorcyclist is less hazardous to the rider as compared to a driver in a collision with only cars involved.* Justify your response.

Nature and development of science

1. List three interventions other than cars that have helped society but that also present risks related to the impact of force.
2. Propose two disciplines of science that may have collaborated to develop each of the inventions you listed in your answer to Question 1.
3. For one of the inventions listed in your answer to Question 1, describe any subsequent inventions that may have been developed to minimise the impact of force (e.g. airbags were invented after the first automobiles, to keep people safe in car collisions).
4. Suggest how engineers' understanding of forces in flight might have led to changes in the design of aircraft. Use the internet to support or refute your suggestions.
5. An old theory of friction considered the roughness of surfaces, but modern science believes that friction is a force that depends on the contact between specific particles. Predict how the following factors led to our current understanding of friction.
   a Sanded wood creates less friction than raw wood of the same type.
   b Aluminium foil and tin foil of the same smoothness create different amounts of friction force.

Processing, modelling and analysing p. 230

In a particular city, the percentage of new cars sold that had airbags was recorded each year. The results were 18% in 2020, 24% in 2021, 32% in 2022, 45% in 2023 and 60% in 2024.

1. Input this data into the table provided:

Year	Percentage of new cars sold with airbags (%)
2020	
2021	
2022	
2023	
2024	

2. Add a column to show the percentage increase over the previous year. Determine and input the values. *Hint:* There will not be a value for 2020, since 2019 is unknown.
3. Display the data in two separate line graphs to show:
   a the percentage of new cars sold with airbags from 2020 to 2024.
   b the increase in the percentage of new cars with airbags from the previous year in 2021 to 2024.
4. Discuss the trends or patterns in each line graph.

Key idea: Systems

Many safety features are examples of 'systems' because they are made up of multiple components that are interrelated to carry out a specific purpose. Give another example of a safety feature that deforms to reduce the impact of a force.

Success criteria

- I can describe some everyday examples of technology that reduces the impact of forces.

8·8 ▸ Simple machines

Learning intention

At the end of this lesson, I will be able to identify some simple machines (e.g. levers, inclined planes, screws, wedges, wheels and axles, and pulleys) and describe how they alter the direction and magnitude of forces.

Key terms

axle: the pin, shaft or rod that a wheel can spin around to transfer force

effort: the force applied to a simple machine to move another object

fulcrum: the point on which a lever turns when moving an object

inclined plane: a sloping or tilted flat surface; also called a ramp

lever: a bar acted upon at different points by two forces

load: an object that is moved or lifted by a simple machine

load force: the force from the object that is being moved

pivot: to turn around a single point or fulcrum

pulley: a wheel with a grooved rim for carrying a cable

Investigation 8.8A

Making a catapult, p. 348

Investigation 8.8B

Using ramps, p. 349

Investigation 8.8C

Modelling a seesaw, p. 350

Investigation 8.8D

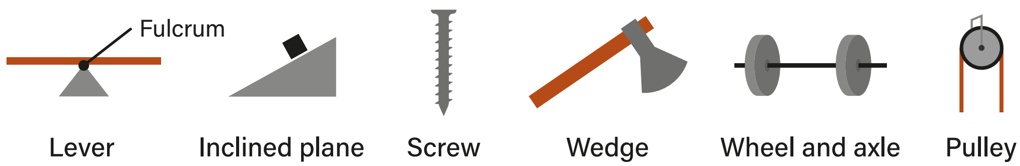
Pulley investigation, p. 351

Key idea: Systems

Machines help make work easier by changing the direction or magnitude (size) of the applied force, or **effort**. Less effort is required when machines are used, either by increasing the size of the force doing the work, or by decreasing the amount of force required to do the work. In this section, you will learn about six different types of simple machines:

- lever
- inclined plane
- screw
- wedge
- wheel and axle
- pulley.

Figure 8.30: Different types of simple machines



Levers reduce the force needed to move objects

Levers help us to lift objects with less effort. They come in a range of shapes and sizes, but the essential parts are basically the same: a rigid arm or beam bar that **pivots**, or turns, on a support called a **fulcrum**. When a force is applied to one end of a lever, the other end is lifted.

A seesaw is a lever with the fulcrum halfway between the end where the effort force is applied and where the **load force** is on the other end. In your experience with seesaws, you might have noticed that the closer to the centre/fulcrum you sat, the easier it was for someone on the other end to move you up and down. This is what makes levers helpful machines:

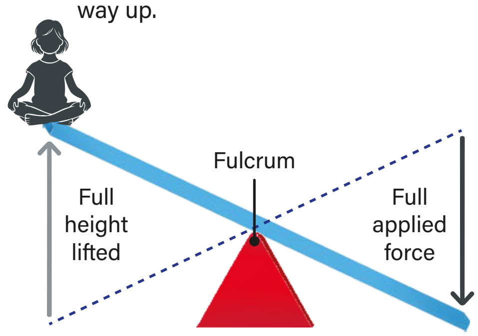
- The closer an object is to the fulcrum; the less force is needed to move it.

You may have also noticed that when you sat near the centre of a seesaw, the height you moved up and down was less. This is the other aspect of a lever:

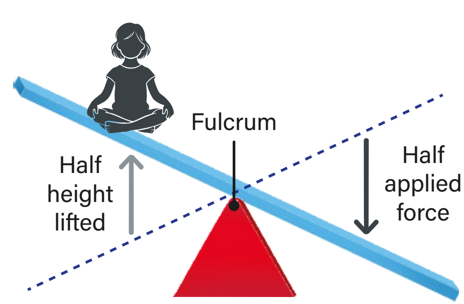
- The closer an object is to the fulcrum, the less distance it can be moved.

Figure 8.31

(a) If you sit on the end of a seesaw, you need a greater mass or force on the other end to lift you all the way up.

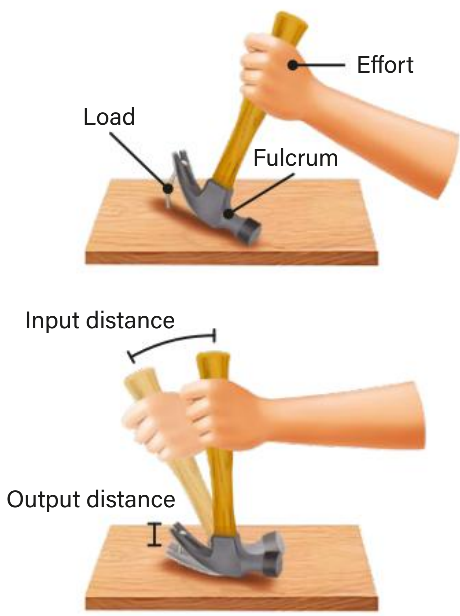


(b) If you sit halfway towards the fulcrum, you only need half the applied force at the opposite end, but you are only lifted half as high as before.



The height that a lever can lift an object depends on the length of the arms on either side of the fulcrum, and on the applied force. If you use a claw hammer to pull out a nail, the handle moves a lot further down than the nail moves up, but less force is needed to pull out the nail, than if you were to pull on the nail directly, without a lever as shown in Figure 8.32.

Figure 8.32: The handle of the hammer moves a greater distance than the nail, minimising the effort required to remove the nail.



There are three classes of levers, depending on the positions of the effort, fulcrum and load, as summarised in Table 8.3.

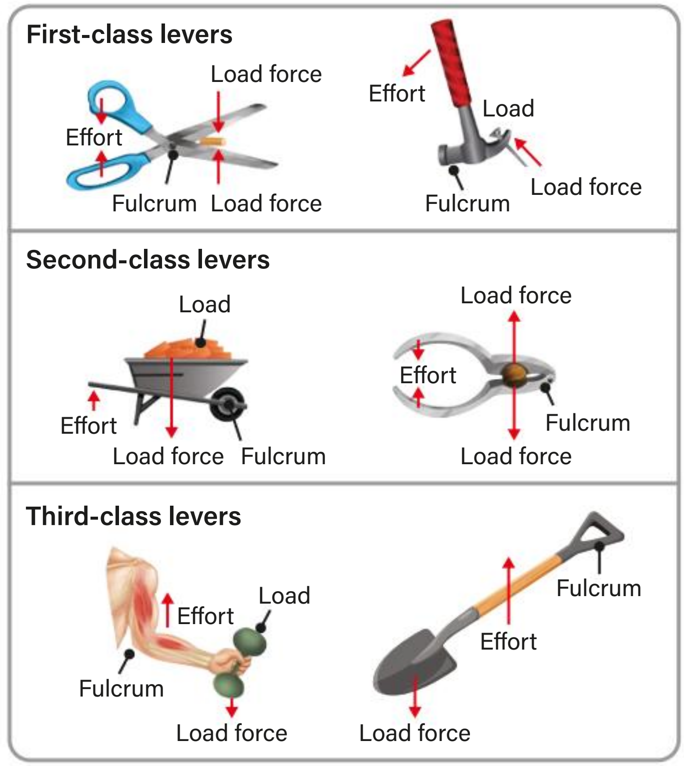
Table 8.3: The three classes of levers

Lever type	Positions of the effort, fulcrum and load	Lever diagram
1st class	The fulcrum is between the effort and the load.	
2nd class	The load is between the effort and the fulcrum.	
3rd class	The effort is between the fulcrum and the load.	

Key: Effort Load Fulcrum

First-class levers apply effort in the same direction as the load force, while second- and third-class levers apply effort in the opposite direction to the load force. A seesaw is a first-class lever. Examples of different types of levers are shown in Figure 8.33.

Figure 8.33: Examples of each of the different classes of levers, including the direction of effort and load force



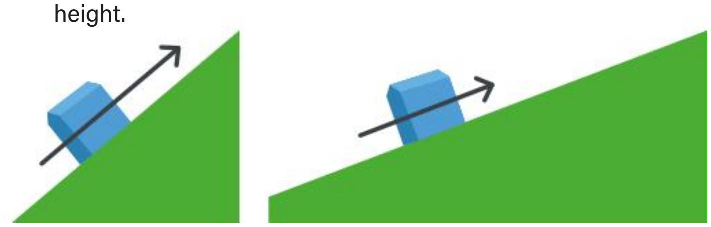
Inclined planes change the direction of force

Rather than lifting an object straight up, it can be moved up a sloping surface, or an **inclined plane**, over a longer distance. An inclined plane reduces the effort force needed to raise an object. This is because it changes the direction of the force you are working against. Instead of the full force going straight down, the force is reduced in a new direction that does not go directly against gravity. It travels at an angle along the surface of the inclined plane, which requires less effort force; however, the distance travelled is greater. Ramps and slides are inclined planes.

Figure 8.34: Inclined planes reduce effort force.

(a) More effort force is required for steeper ramps, but there is less distance to get to the required height.

(b) Less effort force is required for shallower ramps, but there is more distance to get to the required height.



A screw is an inclined plane wrapped around a cylinder

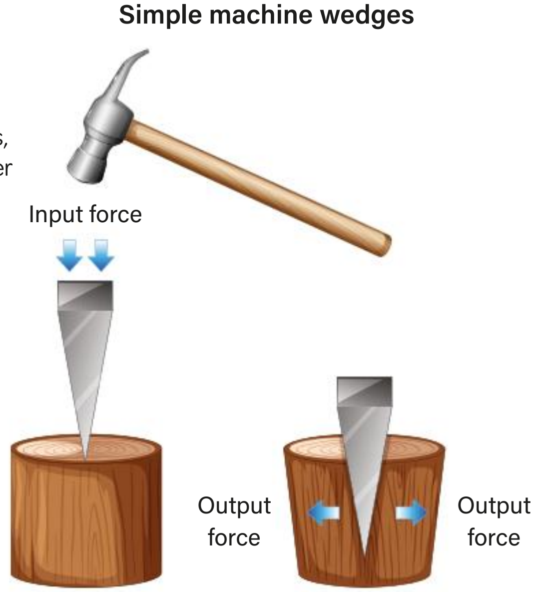
A screw is a modified inclined plane. In the screw, the inclined plane is wrapped around a cylinder in a spiral pattern. It works by twisting the surface of the plane, usually with a screwdriver or drill, effectively spreading the required force over a longer distance, requiring less effort to achieve the same result.

A wedge is two back-to-back inclined planes

A wedge is made of two inclined planes meeting at a point that makes a narrow or sharp edge. This can be used to hold something in place, like a doorstop, or to cut something, like a knife.

The wedge, like an inclined plane, changes the direction of the effort force. For example, the head of an axe used to chop wood is a wedge. When the axe head is forced downwards into the wood, the shape of the wedge causes the force to spread outwards, along the narrow edge. A splitting or separating action is created, making it easier to cut through materials due to the narrow tip and expanding surface.

Figure 8.35: A wedge is made of two, back-to-back inclined planes, used to transfer a downward effort force to an outward resulting force.



A wheel-and-axle system spreads a force

A wheel-and-axle system is also a simple machine used to move or roll things. It is made of two main parts: a wheel and an axle. The wheel is a round object with a rim and a centre, and the **axle** is a rod or shaft that runs through the middle of the wheel.

When force is applied to either the wheel or the axle, it causes the wheel to spin around the axle, allowing movement along the ground. This system makes it easier to move heavy loads because it reduces friction between the object and the ground. The ancient Egyptians used an early version of a wheel and axle to move massive stone blocks when building the pyramids. They placed logs under the blocks so they could roll them from place to place.

Pulleys redirect a force being applied

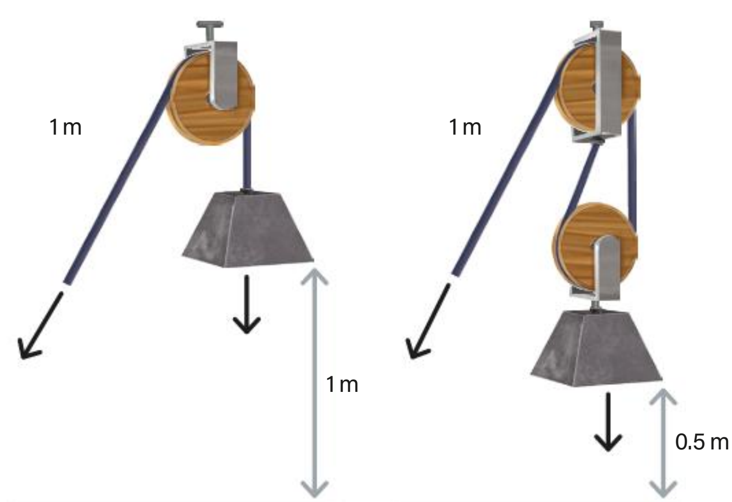
A **pulley** is a wheel with a rope threaded around it. Like an inclined plane, it changes the direction of the force applied to one end of the rope. When you pull the rope, you can lift a **load** attached to the other end. By adding more wheels to the pulley system, you can reduce the amount of force needed to lift the load. However, the trade-off is that the load will move a shorter distance than the length of rope you pull.

For example, using two wheels in a pulley system makes it easier to lift the load by halving the force needed, but the load only moves half the distance of the rope you use to pull with. With three wheels in a pulley, only a third of the original force is needed to lift it, but the load will only move a third of the distance pulled.

Figure 8.36: Increasing the number of pulleys used in a system decreases the effort required to lift the load, but also reduces the distance the load moves as you pull the rope.

(a) When using one pulley, the force to lift an object is equal to the force due to gravity on that object. For every metre you move when pulling the object up, it moves up by a metre.

(b) When using two pulleys, the force to lift an object is half the amount of force due to gravity on that object. For every metre you move when pulling the object up, it only moves up by half a metre.



Simple machines combine to make complex systems

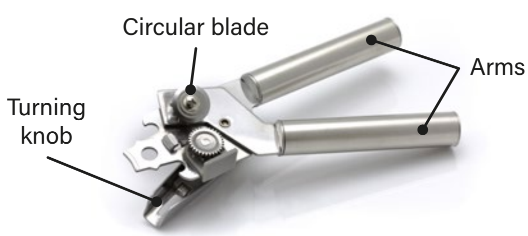
A complex mechanical system is made of two or more simple machines working together to perform a function. In a car, the steering wheel and wheels are on axles, the accelerator and brake pads are levers, and pulleys are used for the fan belt in the engine. A wheelbarrow is a combination of a wheel and an axle, and a second-class lever. These combined simple machines work together to help you lift and move a load.

Simple machines are important because they are the building blocks of the more complex machines that we rely on.

Learning Ladder

Forces and simple machines

1. a There are three types of ________ : first class, _________ class and third class.
   b Modified inclined planes include __________ and ___________ .
   c Pulleys utilise a _________ and _________ machine to spread the force across multiple parts.
2. Describe how an inclined plane reduces the amount of force required to raise an object to a certain height.
3. Propose how to make a first-class lever more efficient.
4. Predict which type of lever, first class or third class, would be more efficient in moving a heavy load using the same amount of force. Use labelled diagrams to support your response.
5. A can opener has a circular blade that cuts the lid of a can as you turn the knob. Discuss the simple machines involved in a can opener with reference to how the size and direction of force is impacted by the different components. Refer to the diagram below to inform your response.



Use and influence of science

1. Identify each of the following as a problem or a solution related to simple machines. Provide a reason for your selection.
   a Transporting a pile of bricks to the tip
   b Using an elevator to get to the top floor of a high-rise building
   c Lifting the curtain in a live theatre production, using a ropes mechanism
2. Propose an example of where a wheel-and-axle machine has impacted society.
3. Explain the example proposed in Question 2, with reference to the size and direction of force.

Evaluating

p. 239

Imagine you are conducting an investigation to see what type of simple machine is the most efficient. You will use a lever, a pulley and a ramp to lift a heavy object 2 m, and you will measure how long it takes. You expect that the machine that gets the job done the quickest is the most efficient.

1. Identify one assumption and one possible source of error in this investigation.
2. Classify the error identified in Question 1 as random or systematic. Describe how this error might impact the results.
3. It took 3 seconds to move the object 2 m using the lever, while the pulley and the ramp took 7 and 9 seconds, respectively. Write a statement that supports these findings using scientific theory related to how simple machines work.
4. Based on the results, the key finding is: '*Levers are more efficient than pulleys or ramps.*'
   a Construct an argument to persuade your school principal to install a lever system instead of a ramp for wheelchair access to the science building.
   b Consider safety and ethical considerations.
5. Your laboratory partner mentions that it was really hard to push the lever that lifted the object, but it was easy to use the pulley and ramp.
   a Evaluate this observation in relation to the investigation aim and method, with reference to effort.
   b Propose and explain how the method could be improved to increase the validity of the results. Refer to effort and the size and direction of force.

Key idea: Systems

A bicycle is a system built with numerous simple machines that all work together. Research the simple machines and components involved in a bicycle system. Prepare an annotated diagram to present to a group of your peers.

Success criteria

- I can identify the different types of simple machines.
- I can describe how simple machines impact the effort needed for different tasks.

8.9 ▶ Aboriginal and Torres Strait Islander Peoples' application of forces to tools

Learning intention

At the end of this lesson, I will be able to identify simple machines included in tools used by Aboriginal and Torres Strait Islander Peoples.

Key terms

grinding: the action of rubbing objects together to break up materials into smaller particles

knapping: the action of applying force to a specific type of rock to create a sharp shard

leverage: the action of a lever

rotation: turning around as if on an axis

Key idea: Systems

Aboriginal and Torres Strait Islander Peoples apply knowledge of forces to create and use tools. Tools are used in agriculture, ceremonies and recreation, and as items for trade.

Friction can be used to make useful items

Coastal and islander communities can access many shells to use as raw materials. Using friction, and applying forces such as pushing and **rotation**, people grind the shells carefully to make fishhooks, wedge tools for cutting and scraping, and parts for ceremonial attire. Many coastal communities traded tools to peoples further inland who did not have this kind of raw material in their communities.

The **grinding** process to create a single fishhook requires enormous skill and patience, and takes significant time. The shell's outer surface is ground on a flat stone to make the shape, then it is fine-polished and sharpened to form a wedge shape.

Woomeras are simple machines

The woomera is a simple machine that uses **leverage** to help throw spears up to three times further. A woomera is a lever made of wood. One end is a handle attached to a paddle-shaped tool. It usually has a bound piece of wood or stone that holds the spear securely in the launch mode. The woomera acts to increase the length of the thrower's arm, and therefore increases the launch speed of the spear.

Figure 8.37: Neville Namarnyilk, a guide, artist and actor from Arnhem Land, demonstrates how a woomera improves spear-throwing distance and accuracy. The lever increases the force transferred from the wrist to the spear.

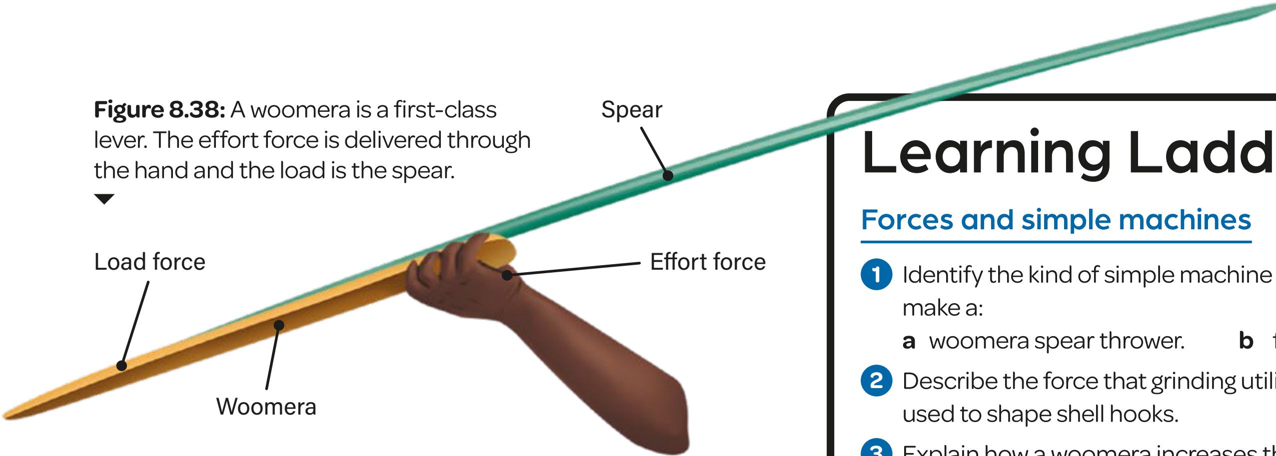


Figure 8.38: A woomera is a first-class lever. The effort force is delivered through the hand and the load is the spear.

A well-constructed woomera allows the spear motion to stay constant and accurate. If an unstable force is applied to a spear by the spear-thrower, this can create unbalanced forces that cause the spear to wobble and slow down, reducing the distance it can travel.

Knapping uses force to create wedge tools

First Nations Peoples have used many stone tools for thousands of years. A common method of creating cutting tools requires the special skill of knapping. **Knapping** is where force is applied to a specific type of rock to create a wedge-shaped sharp edge. The original rock is called a core, and the piece that is removed is a flake. Flakes can be very sharp and can cut into wood or even flesh.

Figure 8.39: A basalt Aboriginal axe head. These large rock flake pieces are often made into axe or spear heads, or sharpened by grinding into various other tools.

Learning Ladder

Forces and simple machines

1. Identify the kind of simple machine that is used to make a:
   a woomera spear thrower. **b** fishhook.
2. Describe the force that grinding utilises when used to shape shell hooks.
3. Explain how a woomera increases the distance a spear can be thrown.
4. Use force diagrams to compare the forces acting on a spear thrown by hand and one thrown using a woomera.

Nature and development of science

1. A woomera makes it easier to harvest food. Propose a problem that would arise if woomeras were not used.
2. Propose why physics and ecology are two disciplines that might have collaborated to develop the woomera.

Questioning and predicting p. 222

1. Identify which of these two questions would be an appropriate scientific question to find out how a woomera works.
   A How does the use of a woomera change how far a spear can be thrown?
   B How many years of experience does a person need before they are able to use a woomera?
2. Make a prediction for the question selected in Question 1.
3. Describe how you could edit the question selected in Question 1 so that it is in an appropriate scientific format.
4. Construct a scientific question focused on the forces required to make a fishhook.
5. Based on the information from this section, develop a hypothesis that investigates the length of a woomera and the maximum distance the spear can be thrown by the same individual.

Key idea: Systems

Investigate other tools used by First Nations Peoples that improve life. Select one and create an infographic to communicate how it is related to forces, simple machines or 'systems'.

Success criteria

- I can identify simple machines included in common tools used by First Nations Peoples.
- I can describe examples of how First Nations Peoples incorporate simple machines into their tools.

8.10 ► Key idea: Systems – a chain reaction machine

Learning intention

At the end of this lesson, I will be able to identify simple machines in a complex system, such as a Rube Goldberg machine.

Key terms

Rube Goldberg machine: a machine or contraption that uses a chain reaction, usually to carry out a simple task

system: a set of simple things that work together to perform a function

Key idea: Systems

A chain reaction machine is a **system** that includes a combination of simple machines that form a series of deliberately complex and interconnected steps. Each small part triggers the next until eventually the end result is achieved. This is what makes it a system. These machines are often creative and entertaining but not practical in terms of completing a task efficiently. Machines like this exist mainly for fun in games and cartoons, but they also provide a wonderful display of how simple machines can be made into complex systems.

A Rube Goldberg machine performs a simple task in a complicated way

Rube Goldberg machines, such as the one in Figure 8.40, are made up of a series of simple objects arranged to trigger a sequence of simple machines to send something like a marble from the start point to the finish. Rube Goldberg competitions are quite popular and attract participants and audiences of all ages.

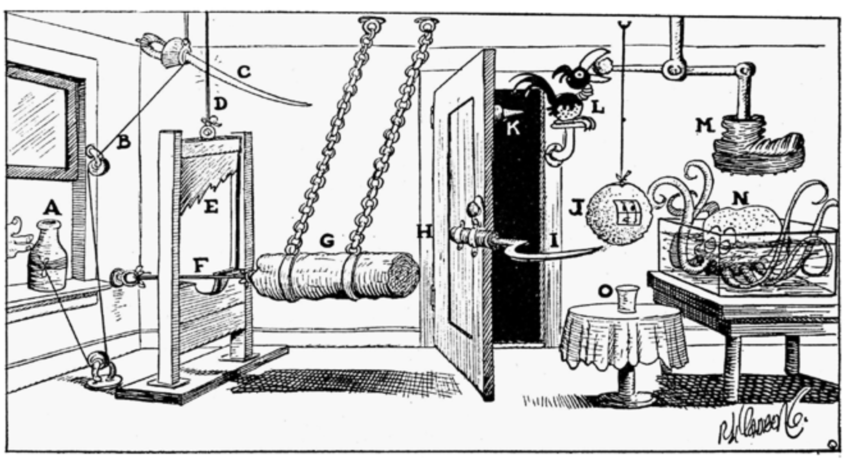
Figure 8.40: A Rube Goldberg machine performs a simple task in a complicated way, using a combination of many simple machines.

Figure 8.41: High school students compete to create a Rube Goldberg contraption that can ice a cake in 20 steps or more.

Rube Goldberg machines utilise simple machines

In Figure 8.42, we can see that the purpose of the system is to squeeze some orange juice, but there are 15 steps instead of just one. Most of the steps involve the use of a simple machine, such as a lever, inclined plane, wedge, pulley, screw, or wheel and axle. In some cases, more than one simple machine is used at the same time; for example, in Figure 8.40, levers and inclined planes are used together. Can you identify the simple machines used in each step in the series that contributes to the chain reaction, and how force is used to carry out a function?

Because these machines were originally drawn for fun and entertainment, not only are they not practical in getting a particular task done, but they might not even be realistic. Can you identify any weaknesses in the machine shown? Are there any factors that are unpredictable and could interrupt the steps?



PROFESSOR BUTTS STEPS INTO AN OPEN ELEVATOR SHAFT AND WHEN HE LANDS AT THE BOTTOM HE FINDS A SIMPLE ORANGE SQUEEZING MACHINE. MILK MAN TAKES EMPTY MILK BOTTLE (A) PULLING STRING (B) WHICH CAUSES SWORD (C) TO SEVER CORD (D) AND ALLOW GUILLOTINE BLADE (E) TO DROP AND CUT ROPE (F) WHICH RELEASES BATTERING RAM (G). RAM BUMPS AGAINST OPEN DOOR (H) CAUSING IT TO CLOSE. GRASS SICKLE (I) CUTS A SLICE OFF END OF ORANGE (J) AT THE SAME TIME SPIKE (K) STABS "PRUNE HAWK" (L) HE OPENS HIS MOUTH TO YELL IN AGONY, THEREBY RELEASING PRUNE AND ALLOWING DIVER'S BOOT (M) TO DROP AND STEP ON SLEEPING OCTOPUS (N). OCTOPUS AWAKENS IN A RAGE AND SEEING DIVER'S FACE WHICH IS PAINTED ON ORANGE, ATTACKS IT AND CRUSHES IT WITH TENTACLES, THEREBY CAUSING ALL THE JUICE IN THE ORANGE TO RUN INTO GLASS (O).
LATER ON YOU CAN USE THE LOG TO BUILD A LOG CABIN WHERE YOU CAN RAISE YOUR SON TO BE PRESIDENT LIKE ABRAHAM LINCOLN.

Figure 8.42: An elaborate Rube Goldberg machine invented by cartoon character Professor Lucifer Butts

You can create your own Rube Goldberg machine

You do not need anything fancy to make your own version of a chain reaction machine. Things like empty paper towel rolls, string, paper cups, small toys and marbles may be all you need to build a contraption that utilises a variety of simple machines. Be creative and design a system using at least three simple machines you have learnt about that will carry a marble from one position to another. What will you create?

Learning Ladder

Forces and simple machines

Consider the chain reaction system shown in Figure 8.42.

1. Identify three simple machines and where they are in the chain reaction machine.
2. Describe how force is used in part 'G' of the system.
3. Select a step included in the cartoon that you think is particularly clever. Explain the role of the objects and forces involved that leads to the intended change.
4. Construct a labelled force diagram to predict the effect of part 'L' of the system.
5. A perpetual motion machine can perform a function forever, without friction as a factor. Justify why this type of system is only hypothetical.

Use and influence of science

1. Identify the ethical issue associated with part 'N' of the system shown in Figure 8.42.
2. Describe how scientific knowledge is used to construct a Rube Goldberg machine. Propose how this has contributed to society in a positive way.

Evaluating *p. 239*

Consider the chain reaction system shown in Figure 8.42.

1. Identify an assumption that is made in part 'K'.
2. Imagine the orange slice knocks over the cup in part 'I' of the system, preventing it from filling with juice at the end. Classify this as a random or systematic error. Provide a reason.

Success criteria

- I can identify simple machines in a complex system, such as a Rube Goldberg machine.
- I can design a system using at least three simple machines working together to perform a function.

Summary

- A force can be a push, a pull or a twist.
- Forces can be direct (objects are in contact) or indirect (objects are not in contact).
- Forces occur when objects interact with each other.

- Balanced forces cause an object to continue what it is doing, such as staying still.
- Unbalanced forces cause an object to change its motion, like a skateboarder pushing off a walkway.
- Changes in an object's motion can be related to its mass and the magnitude and direction of the forces acting on it.

Balanced forces

Two forces are the same size but opposite in direction.

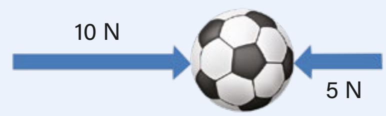
They cancel each other out.

The net force is equal to 0 N.

Unbalanced forces

Two forces are different sizes and opposite in direction.

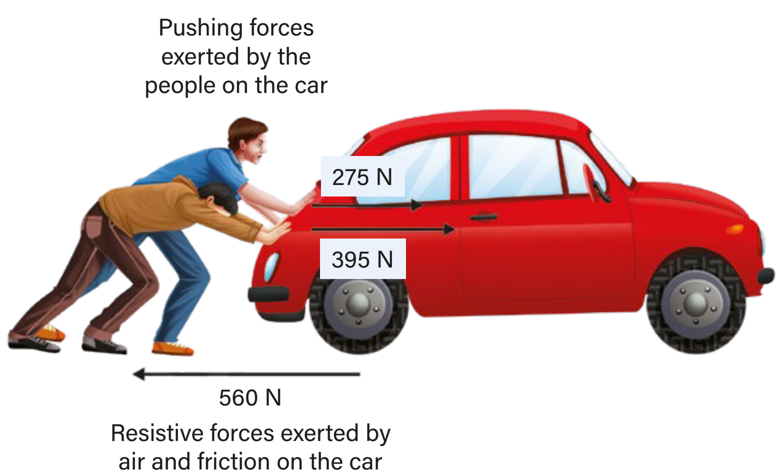
They do not cancel each other out.

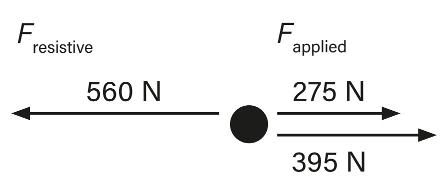


The force pushing the ball to the right is bigger than the force pushing to the left. The net force is equal to 5 N to the right.

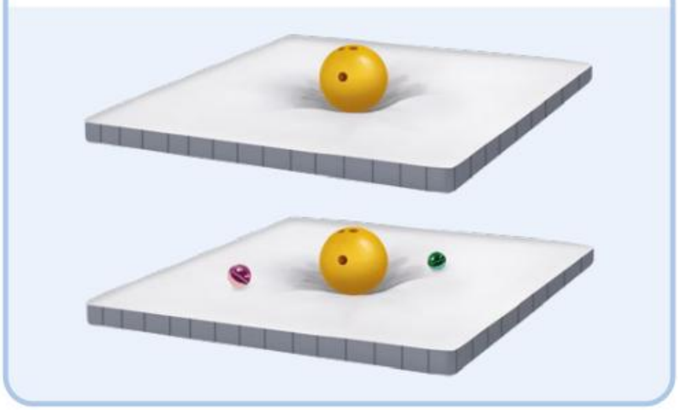
- Friction is a force that resists an object's motion and produces heat.

- Balanced and unbalanced forces acting on objects, including gravitational force, may be represented using force diagrams.
- Force diagrams show the size of forces acting on an object and can be used to determine whether it is stationary or moving.
- The net force is the sum of all the forces acting on an object.

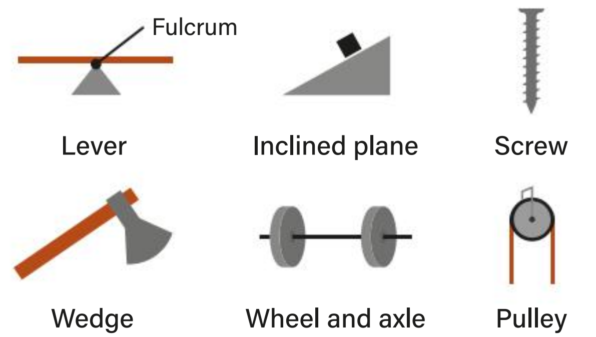




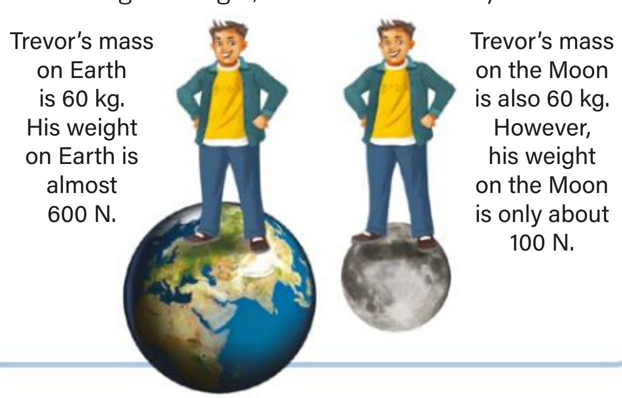
- Gravitational force is a force of attraction between objects with mass. The more mass the object has, the bigger its gravitational force.
- The Sun's gravity pulls on moving planets, which keeps them in their orbits. (e.g. marbles will roll towards a bowling ball on a mattress).
- The mass of an object is the same no matter where it is in the solar system.



- Simple machines reduce the amount of effort required to carry out tasks.
- Levers, inclined planes, screws, wedges, wheels and axles, and pulleys are all types of simple machines.
- A wheelbarrow uses a wheel and a lever to help move loads with less force.
- Simple machines change the magnitude (size) and direction of force required to do work.



- An object's mass is the amount of matter it contains, measured in grams (g) or kilograms (kg).
- An object's weight is a measurement of how much gravitational force is pulling on it, measured in newtons (N).
- Changing the gravitational force acting on an object will change its weight, even when mass stays the same.



Aboriginal and Torres Strait Islander Peoples make and use a variety of tools or machines, including the woomera, which acts as a lever.

- Technological advances help to reduce the impact of forces in everyday life.

Key idea: Systems

A Rube Goldberg machine is a system made up of many simple machines working together to carry out a silly yet entertaining chain reaction.

Masterclass

Steps in progression

		1	2
Science understanding	Forces and simple machines	Identify two forces that help to increase the speed of maglev trains.	Describe how each force identified in step 1 works to increase the speed at which a maglev train can travel.
Science as a human endeavour	Nature and development of science	Identify one factor that makes traditional trains inefficient.	Propose why it may be important for engineers, physicists and city planners to work together on the maglev train initiative.
Science as a human endeavour	Use and influence of science	True or false: Maglev trains will solve socio-scientific issues in Australia.	Describe how introducing the maglev train could address economic as well as environmental issues.
Science inquiry	Questioning and predicting	Identify whether this question can be investigated scientifically: How fast can a Maglev train travel?	Predict the impact of changing the shape of the front of a maglev train to make it look more like a truck.
Science inquiry	Processing, modelling and analysing	Identify two proposed maglev train routes from the data in Figure 8.44.	Construct a table showing possible routes of the maglev train.
Science inquiry	Evaluating	Identify an assumption we make about the strength of the magnetic forces and the size of the maglev train that allow it to hover above the tracks.	Identify and describe the type of error that would arise from a consistently high magnetic force recorded on the tracks, due to poor calibration of the measuring device.

Maglev trains set to glide into Australia

Traditional trains are not very efficient, due to the large amount of friction force that creates resistance to movement and wastes usable energy as heat. But a new train concept is on the horizon, designed to use forces to their advantage. Maglev trains are high-speed vehicles that can travel more than 500 kilometres per hour. ‘Maglev’ is short for ‘magnetic levitation’, which explains how these trains work: they utilise magnetic forces that push the train up and away from the tracks, allowing them to glide or hover freely, which significantly reduces friction forces. Maglev trains also have a streamlined design and smooth outer shell that minimises drag; these factors help to increase the speed at which these trains can travel. In Australia, scientists are exploring what would be involved in setting up maglev train routes between Brisbane, Newcastle, Sydney and Melbourne. Imagine a trip from Melbourne to Sydney taking only 2 hours instead of 11 hours!

Demonstrate your understanding

3	4	5	
Explain how the force of gravity is linked to the movement of maglev trains.	Compare the roles of friction, gravity, magnetism and drag in relation to starting and stopping a maglev train.	Identify and evaluate the simple machines that might be used in the development of a maglev transport system.	
Explain how magnetic forces are relevant in designing new types of trains like the maglev.	Discuss how our improved understanding of balanced and unbalanced forces has contributed to the maglev idea.	Some people may worry about exposure to strong magnets. Discuss whether this is a reasonable worry.	
Propose and explain one impact the maglev train could have on traditional train networks.	Discuss how the impact proposed in step 3 could affect other industries besides transportation.	Predict and analyse how public viewpoints about using forces to improve transportation could change after maglev trains are introduced.	
Construct a question to investigate how the material a train is made of impacts the top speed at which it can travel.	Create a scientific hypothesis that states what you expect to be the result of the investigation in step 3.	**a** Identify all variables of the investigation in step 3. **b** Are these all included in your prediction? Make any required improvements.	Science how-to p. 222
Determine the average speed a maglev train would travel at between Newcastle and Sydney (see Figure 8.44).	Use the average speed determined in step 3 to identify any trends related to travelling between cities.	Evaluate the feasibility of having maglev trains in Australia. Might some routes be more popular than others?	Science how-to p. 230
Explain why a greater magnetic force would result in a maglev train hovering further above the tracks.	Construct a letter to your local council to persuade them to build a maglev train system. Include referenced theory to support your argument, as well as public perspectives.	Your letter from step 4 was dismissed by the council. Write a response letter that challenges their perspective, including suggestions to address problems and conflicting views.	Science how-to p. 239

Figure 8.43: Smooth, curved outer surfaces help to increase the speed of maglev trains.

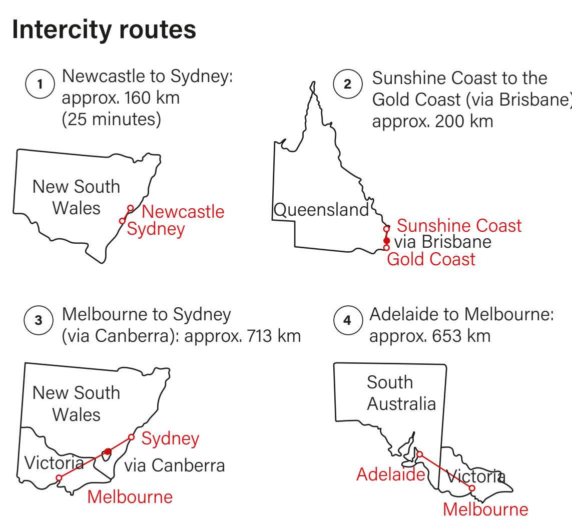
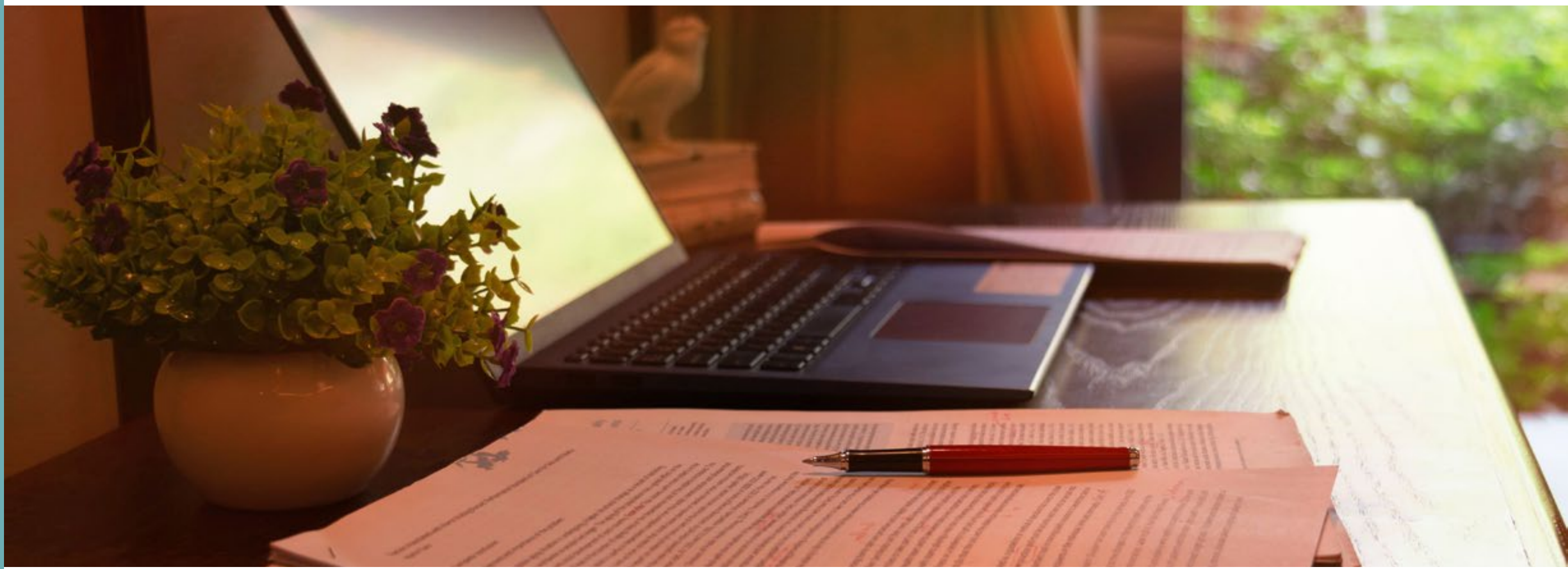


Figure 8.44: Potential maglev train routes in Australia

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.

S1 Command terms and response modelling



Command terms are the instruction words in a question. They tell you the approach to use when you answer it.

The command terms are listed alphabetically over the following pages. We have also included an example of how they would be used in a question and a sample response.

Account for	
Explanation	State reasons for; report on.
Sample question	Account for the movement of a ball down a slope.
Sample response	*A ball moves down a slope as a result of unbalanced forces. The force of gravity pushes down on the ball, causing it to accelerate down the slope. The force of friction between the ball and the slope is smaller than the force of gravity, so friction does not stop the ball from moving.*

Analyse	
Explanation	Identify components/elements and the significance of the relationship between them; draw out and relate implications; determine logic and reasonableness of information.
Sample question	Analyse the link between Earth, the Sun and the seasons.
Sample response	*Earth's movement is responsible for the changing seasons. Earth is tilted on its axis. This means that during part of Earth's orbit around the Sun, the lower half of Earth is tilted closer to it. Being tilted towards the Sun causes the southern hemisphere to receive more direct sunlight and experience summer, while the northern hemisphere, receiving less sunlight, experiences winter.* *During the opposite part of Earth's orbit, the upper half of Earth is tilted towards the Sun. The tilt causes the northern hemisphere to experience summer, while the southern hemisphere experiences winter.* *Earth moves between these positions in its orbit, causing the tilt to be 'side on' to the Sun. The other seasons – spring and autumn – occur when Earth is moving from one hemisphere being tilted towards the Sun to the other being tilted towards the Sun.*

Apply

Explanation	Use; employ in a particular situation or context.
Sample question	Apply your understanding of Linnaean classification to the following organisms: ▪ orca. ▪ ring-tailed possum.
Sample response	*The Linnaean classification system classifies organisms from broad to specific categories. The organisms above would be classified as follows:*

Category	Orca classification	Ring-tailed possum classification
Domain	Eukarya	Eukarya
Kingdom	Animalia	Animalia
Phylum	Chordata	Chordata
Class	Mammalia	Mammalia
Order	Cetacea	Diprotodontia
Family	Delphinidae	Pseudocheiridae
Genus	*Orcinus*	*Pseudocheirus*
Species	*orca*	*peregrinus*

Assess

Explanation	Make a judgement about, or measure, determine or estimate, the value, quality, outcomes, results, size, significance, nature or extent of something.
Sample question	Assess the effectiveness of using solar energy to reduce household power costs.
Sample response	*Solar energy is energy from sunlight that is converted by panels into usable electrical energy.* *For:* • *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.* *Against:* • *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	Determine from given facts, figures or information; obtain a numerical answer showing the relevant stages in the working; determine or find (e.g. a number, answer) by using mathematical processes.
Sample question	Conduct a first-hand investigation to determine the distance travelled by a model car with wheels made from milk bottle caps. Calculate the average distance travelled over three trials.
Sample response	*The bottle cap wheel travelled 11 cm in trial 1, 9 cm in trial 2 and 13 cm in trial 3.* *This means the average distance travelled = (11 + 9 + 13) ÷ 3 = 11 cm.*

Figure S1.1: Renewable energy can be generated by wind, sunlight or water.

Compare	
Explanation	Recognise similarities and differences and the significance of these similarities and differences.
Sample question	Compare the use of renewable and non-renewable resources in energy production.
Sample response	*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, create or put together by arranging ideas or items (e.g. an argument, artefact or solution); display information in a diagrammatic or logical form.
Sample question	Construct a poster, diagram or presentation to show your understanding of the solar system.
Sample response	Different versions of responses to this question are shown in the 'Presenting scientific information' section on page 251.

Define	
Explanation	Give the precise meaning and identify essential qualities of a word, phrase, concept or physical quantity.
Sample question	We learnt about forces in Chapter 8. Define the term 'balanced force'.
Sample response	*When forces of equal strength are pushing on an object in opposite directions.*

Describe	
Explanation	Provide characteristics, features and qualities of a given concept, opinion, situation, event, process, effect, argument, narrative, text, experiment, artwork, performance piece or other artefact in an accurate way.
Sample question	A solvent is a substance, usually a liquid, that can dissolve another substance to make a solution. Describe how water acts as a solvent.
Sample response	*Water is a liquid that is able to dissolve the particles of other substances (solutes); it can become a solution with those dissolved particles by breaking their chemical bonds.*

Discuss

Explanation	Present a clear, considered and balanced argument or prose that identifies issues and shows the strengths and weaknesses of, or points for and against, one or more arguments, concepts, factors, hypotheses, narratives and/or opinions.
Sample question	Discuss the use of non-renewable energy such as coal for large-scale electrical energy generation.
Sample response	*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.* *For:* • *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.* *Against:* • *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	Make clear the differences between two or more arguments, concepts, opinions, narratives, artefacts, data points, trends and/or items.
Sample question	Solids, liquids and gases are discussed in Chapter 4. Distinguish between liquids and gases.
Sample response	*Liquids contain vibrating particles that are next to one another and are able to 'slide' past one another. They will take the shape of any container they are put into. Gases have particles that vibrate and move around separately from one another, taking up the entire space of the container they are in, with large gaps between the particles.*

Evaluate

Explanation	Ascertain the value or amount of; make a judgement using the information supplied, criteria and/or own knowledge and understanding to consider a logical argument and/or supporting evidence for and against different points, arguments, concepts, processes, opinions or other information.
Sample question	Evaluate the use of wind energy as a power source, taking into account levels of pollution and reliability of the energy source.
Sample response	*Wind energy is a renewable form of electricity that uses turbines to transform kinetic energy into electrical energy.* *For:* • *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.* *Against:* • *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 they reduce the amount of pollution in the atmosphere.*

Examine	
Explanation	Consider an argument, concept, debate, data point, trend or artefact in a way that identifies assumptions, possibilities and interrelationships.
Sample question	Examine the argument, 'We should gain 100 per cent of our energy needs from renewable sources.'
Sample response	*Renewable energy sources are ways of generating electrical energy that are able to be continuously renewed. These methods of electricity production typically do not produce waste products, making them better for the environment. However, our global energy demands are currently much higher than our ability to use renewable sources for all of our power generation. Instead, we should focus on putting more structures for renewable energy generation in place, so we can switch across from non-renewables without preventing access to electricity around the world.*

Explain	
Explanation	Give a detailed account of why and/or how, with reference to causes, effects, continuity, change, reasons or mechanisms; make the relationships between things evident.
Sample question	Explain how energy moves through an ecosystem. (Ecosystems are explained in Chapter 3.)
Sample response	*Energy is able to move through an ecosystem via living things. 'Producers' such as plants use energy from sunlight to produce glucose, which can be used as chemical energy. When a 'consumer', such as a grasshopper, eats a plant, it takes in and uses the plant's energy. Then, a consumer like a bird eats the grasshopper, and the energy is transferred again. When the bird dies and lands on the surface of the ground, decomposers such as bacteria break it down using the energy from the bird and form nutrients for plants to absorb while they are growing. This cycle continues, providing energy to all organisms in the ecosystem.*

Extrapolate	
Explanation	Infer and/or extend information that may not be clearly stated from a narrative, opinion, graph or image by assuming existing trends will continue.
Sample question	Looking at the graph, extrapolate what will happen when the temperature of the water is 70 °C.
Sample response	*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.*

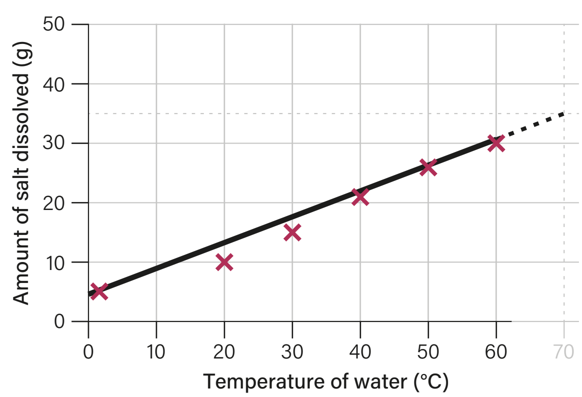


Figure S1.2: A graph showing how much salt is dissolved as water temperature increases.

Identify	
Explanation	Recognise and name and/or select an event, feature, ingredient, element, speaker and/or part from a list or extended narrative or argument, or within a diagram, structure, artwork or experiment.
Sample question	As discussed in Chapter 8, identify the term used to describe a push, pull or twist.
Sample response	*Force.*

Investigate	
Explanation	Observe, study or carry out an examination in order to establish facts and reach new conclusions.
Sample question	n/a
Sample response	Investigating is covered in the 'Writing investigation reports' section on page 250.

Justify	
Explanation	Show, prove or defend, with reasoning and evidence, an argument, decision and/or point of view using given data and/or other information.
Sample question	Justify the use of water filtration in waste management.
Sample response	*Water filtration should be used in waste management. Filtering water means we can easily remove large particles that are not dissolved. This means that waste products such as plastics can be removed from waterways before the water is reintroduced to the environment.* *Filtering water can also remove tiny particles of sewage from waste. Using pumps, sewage is sent through microfilters that are capable of removing tiny solids and even some harmful bacteria. This improves water quality and stops harmful agents from being released into the environment.*

Figure S1.3: Water filtration systems remove impurities and waste products.

Outline	
Explanation	Provide an overview or the main features of an argument, point of view, text, narrative, diagram or image.
Sample question	Outline what happens to the particles of a substance as it changes from a solid to a liquid.
Sample response	*The substance is melting – heat energy is being absorbed, causing the particles of the substance to vibrate faster and move further apart.*

Figure S1.4: We can test how sunlight affects plant growth.

Predict	
Explanation	Give an expected result of an upcoming action or event; suggest what may happen based on available information.
Sample question	Predict the effect of sunlight on the growth of tomato plants.
Sample response	*If a tomato plant receives a lot of sunlight, then it will grow taller than tomato plants that receive little light.*

Propose	
Explanation	Suggest or put forward a point of view, idea, argument, diagram, plan and/or suggestion based on given data or stimulus material for consideration or action.
Sample question	Propose a reason for wearing safety glasses when using a Bunsen burner to heat water.
Sample response	*When water heats up, it starts to boil and changes state from a liquid to a gas. This means that it bubbles and may splash out of its beaker. Wearing safety glasses prevents the water from splashing into your eyes and causing damage.*

Recall	
Explanation	Present remembered ideas, facts and/or experiences.
Sample question	Recall the common characteristics of all living things.
Sample response	*All living things have the following characteristics:* • *They are made of cells.* • *They are made of molecules containing carbon.* • *They are able to grow, move and reproduce.* • *They are able to respond to stimuli.*

Summarise	
Explanation	Retell concisely the relevant and major details of one or more arguments, text, narratives, methodologies, processes, outcomes and/or sequences of events.
Sample question	Summarise the two groups that animals can be classified into.
Sample response	*The kingdom of animals can be classified into two groups. One is vertebrates, which includes all animals that have a backbone, such as humans. The other is invertebrates, and this group consists of all animals that do not have a backbone, such as insects.*

S2 Science inquiry

Key terms

accuracy: how close a measured value is to the true, exact value; how closely a recorded value matches the expected outcome of an investigation

anomalies: data points or findings that do not follow the normal trend or expected findings

controlled variable: variable in an investigation that must be kept the same for all trials. Only the independent variable should change, otherwise it is not a fair test

correlation: a relationship between two factors or variables that shows them changing together, in either the same or opposite way

data: facts and information collected for reference or analysis

data point (datum): a single identified element in a dataset

dataset: a collection of data, often from numerous trials related to a single factor

dependent variable: the thing that is measured in a first-hand investigation

ethical: in science, minimising harm to those involved, and ensuring investigations are conducted honestly and data is collected and recorded accurately

evaluate: judge value based on scientific evidence

fair test: a test where all variables are kept the same, except for the independent variable and the dependent variable

hazard: something that can harm living things, objects or the environment

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

independent variable: the thing that is deliberately changed in a first-hand investigation

pattern (data): when data repeats in a predictable way

plausible: could be reasonably accepted based on available evidence

precision: how close measured values are to each other within a dataset

raw data: data that is collected directly from the investigation

relationship: a link between two factors

trend (data): when data moves in a general direction, usually up or down

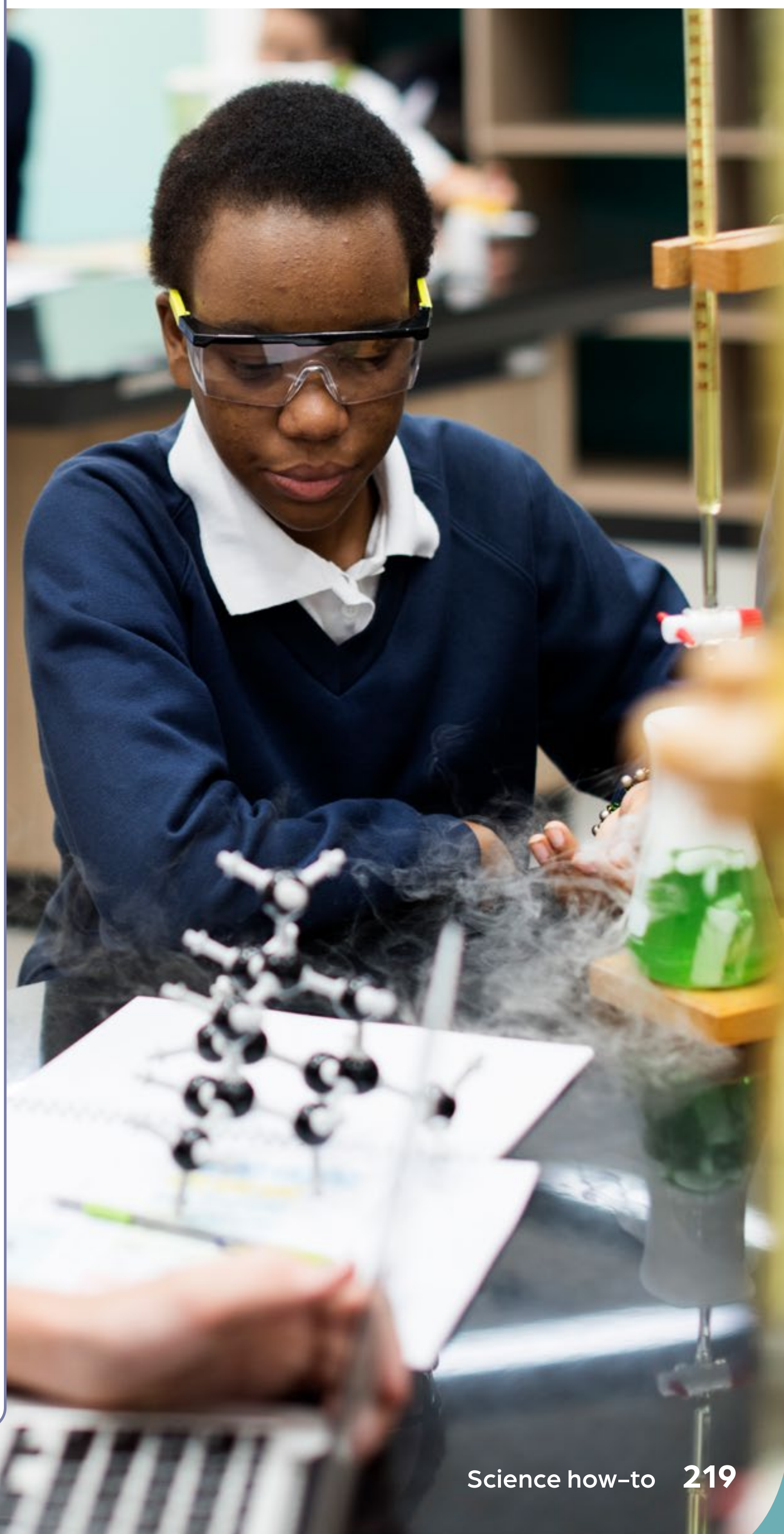
true value: the actual, exact value of a measurement, error-free, which would be obtained if a perfect measurement were made

validity: when an investigation meets its intended purpose

variable: a factor in an investigation or a model that can be changed, measured or controlled

Science has its own skills that scientists use to conduct investigations and test their ideas. Science inquiry allows you to collect information and test your ideas about how different parts of the world work.

▼ **Figure S2.1:** Inquiry is a fundamental part of science.



Unpacking science inquiry

Science inquiry comprises five skills:

1 Questioning and predicting
2 Planning and conducting
3 Processing, modelling and analysing
4 Evaluating
5 Communicating.

This section will break down each skill for you – where to begin, how you can apply it as you learn more, and how mastering the skill will elevate your science learning.

The Learning Ladder and science inquiry

The Learning Ladder at the start of each chapter lists three of the five science inquiry skills (three have been selected for each chapter) and the five steps of progress for each of these skills.

Figure S2.2 shows the five science inquiry Learning Ladders, with step 1 being the first level and step 5 the final, most challenging level. You can only climb the ladder by mastering each step. This approach is called developmental learning and puts students in charge of their own learning progress.

Figure S2.2: Start at step 1 and work your way up to mastery.

Learning Ladder

Steps in progression	Questioning and predicting	Planning and conducting	Processing, modelling and analysing
5	I can evaluate investigation questions and predictions for scientific validity	I can design and conduct reproducible investigations that consider safety, ethical and procedural factors	I can analyse processed data for patterns, trends, relationships and anomalies
4	I can develop a hypothesis that predicts the relationship between investigation variables	I can generate and record data with precision, using digital tools as appropriate	I can identify and discuss trends and/or patterns in a range of dataset representations
3	I can construct questions and predictions to investigate scientific problems	I can distinguish between variables to be changed, measured and controlled in an investigation	I can process data by using mathematical relationships and/or constructing graphs
2	I can make simple predictions based on what I know and observe	I can describe ways to minimise risks for a range of investigations	I can organise and display data using tables, keys and/or models
1	I can recognise questions that can be investigated scientifically	I can identify and select appropriate equipment for scientific investigations	I can identify data from tables and graphs

Science inquiry skills

Each section of this book contains a Learning Ladder question block. The questions relate to both content and inquiry skills. Question 1 corresponds to step 1, Question 2 corresponds to step 2, and so on.

The green headings mean these are science inquiry questions. They will test you on a specific skill, such as communicating. There is a page reference to the Science how-to section, where you can get more information on what is required at each step.

Learning Ladder

Classification

1. Identify two physical features of macropods.
2. Identify the seven biological characteristics of all living things used in classification.

Use and influence of science

1. Identify an issue we would face if we could not categorise organisms in the world around us.
2. Describe how knowledge of classification can be useful in countries like Australia, which has many dangerous and venomous creatures.

Communicating p. 245

1. Identify three scientific terms used when listing the seven biological characteristics of living things.
2. Describe a way you could communicate information about the diet of the quokka.

Success criteria

- I can describe why the use of classification systems is important.

Next we will consider each science inquiry skill and break down what is required at each step of the Learning Ladder to develop your skills and achieve process mastery.

Steps in progression	Evaluating	Communicating
5	I can evaluate conclusions and claims with reference to conflicting evidence and unanswered questions	I can communicate scientific findings and arguments for specific purposes to specific audiences
4	I can create evidence-based arguments to justify conclusions or evaluate claims	I can use digital technologies to organise and communicate data and information
3	I can use science-based explanations to support investigation findings	I can prepare a variety of representations to communicate ideas and findings
2	I can describe different types of errors in an investigation method	I can select appropriate formats to communicate ideas and findings
1	I can identify errors and assumptions in an investigation	I can identify scientific terminology used to communicate information

Questioning and predicting

Questioning is the basis of all science. By asking questions, we can come up with ideas that we can test scientifically. Predicting scientific outcomes helps us to make better decisions. Predicting weather patterns can help people prepare for extreme temperatures, while predicting which illnesses might spread rapidly can help health-care workers adapt their treatments. By making accurate predictions, scientists can solve real-world problems and improve the quality of human life.

Step 1 I can recognise questions that can be investigated scientifically

Scientific questions contain one factor that we can change during an investigation and one factor we can measure. Doing this means that we can test the question by setting up a first-hand investigation. We usually write scientific questions in the following format:

How does *changing one factor* affect the factor that *can be measured*?

When checking if a question can be investigated scientifically, you need to check that only *one* thing changes in the question and that there is *one* thing you can measure. If more than one thing is changed, it is not possible to know which thing caused the effect. This is why only one thing can change, while everything else is controlled or kept the same. Controlled variables are discussed more in the 'Planning and conducting' section on page 226. Table S2.1 shows what to look for.

Table S2.1: What to look for when setting up an investigation

Question	Thing changed	Thing you can measure	Can it be investigated?
How does the amount of sunlight a plant receives affect how tall it grows?	The amount of sunlight the plant gets	How tall the plant grows	Yes
How can I look after my plants at home?	Many things – anything you do to look after your plants	None	No

The first question in Table S2.1 *can* be investigated, as there is one thing we can change and one thing we can measure. The second question *cannot* be investigated, as there is nothing to measure and many things we can change.

Figure S2.3: The changed factor has an effect on the measured factor.

Step 2 I can make predictions based on prior observations

When you are writing questions and making predictions, you need to ensure you are proposing things that are **plausible**. To help you predict something plausible, you can think back to experiences you have had or match the investigation to a relevant scientific theory you already know.

Figure S2.4: The observation of a hot-air balloon in the sky supports the prediction that heat can make objects rise.

For example, if you have a herb garden at home, you may have observed that the parsley grown in the shade does not grow as tall as the parsley in full sunlight. Add 'because' to your prediction (or 'if ..., then ...' statement; see step 4):

If a tomato plant gets more sun, *then* it will grow more *because* the parsley in full sun in my garden grows taller than parsley in the shade.

You can use this experience to predict how the amount of sunlight will affect the growth of tomatoes. Other examples of experiences that can help you to make predictions are:

- slipping on a puddle of water on tiles but not on a similar-sized puddle on concrete
- noticing someone bigger than you is faster when you roll down a steep hill on your bikes
- seeing a hot-air balloon in the sky and being told that the heat from the flames makes the balloon lift off the ground.

Step 3 I can construct questions and predictions to investigate scientific problems

We call the factors that we change and measure in the scientific question the **variables**. The factor that we change is called the **independent variable**. The factor that we measure is called the **dependent variable**. We want to see if there is a **relationship** between these two variables. In our scientific question structure, this looks like:

How does the *independent* variable affect the *dependent* variable?

For example, we may have the following scientific problem: The tides at the beach change throughout the day, depending on where the Moon is in relation to Earth. So our question is:

How does the *location of the Moon* affect the *height of a tide* in the oceans?

The independent variable is the location of the Moon. The dependent variable is the height of the tides. The additional step is to identify the relationship. In our example, we are testing the relationship between location and height.

Figure S2.5: ▶ The Moon directly affects the tides of the oceans – but how?

The next step is to use scientific knowledge to help you make predictions. To link your prediction to scientific knowledge, you must match the content of your knowledge to the investigation factors. Your prediction statement will then be followed by a 'because':

If the moon is directly over an ocean, *then* there will be a high tide *because* the moon's gravity pulls on the water.

The scientific knowledge you use can be general – you do not need to include specific details. However, it must be relevant to the investigation and the predicted effect.

Step 4 I can develop a hypothesis that predicts the relationship between investigation variables

Now that you can write and support a prediction in general, you can update your prediction with the specific variables of the investigation. This means we can also look at the relationship between the variables.

The following method will help you to formulate a scientific **hypothesis**:

a Read the question.

b Identify the independent variable.

c Identify the dependent variable.

d Identify some **controlled variables**.

Step 4 requires more detail on how you will change the independent variable to test your hypothesis, the relationship with the dependent variable and the predicted effect.

Once you have identified and understood your variables, include them in your prediction using the following template:

If [the independent variable and the specific change],
then [the dependent variable and the predicted effect].

So your hypothesis will become:

If the amount of sunlight a tomato plant receives is increased,
then its growth will increase by a similar amount.

Figure S2.6: There can be a variety of relationships between independent and dependent variables. Scientific knowledge and our own experiences can help us to predict what that relationship will be.

Step 5 I can evaluate investigation questions and predictions for scientific validity

Once scientific questions and predictions are constructed, they must be **evaluated** to determine their scientific **validity**. This means the investigation should measure what it intends to measure.

To evaluate whether this is the case, you can use the following steps:

a Read the question and prediction.

b Identify the independent and dependent variables. Is there one of each?

c Identify some controlled variables.

d Make a judgement on whether or not this is a good scientific question or prediction.

e If needed, suggest any improvements and rewrite the question and/or prediction.

Table S2.2: Evaluating scientific questions by identifying the variables

1 How does the *amount of sunlight* a plant receives affect how *tall it grows*?	
Independent variable	Amount of sunlight the plant receives
Dependent variable	Height of plant
Controlled variables	None
Judgement	This is a good scientific question that changes only one factor; however, it needs to include the controlled variables to make it better, such as the type of soil, the amount of water given and the temperature of the room, all of which must be kept the same.
Improvement	This question could be improved by controlling the variables – the conditions that plants are grown in. For example, how does the amount of sunlight a plant receives affect how tall it grows when it is in the same conditions, including soil type, amount of water, temperature and fertiliser provided?
2 How does the *location of the Moon* affect the *height of a tide* in the oceans?	
Independent variable	Moon location
Dependent variable	Tide height
Controlled variables	One – location of the ocean in relation to the Moon
Judgement	This is an excellent scientific question that includes one changed and one measured variable, as well as a way to control the investigation. No improvements are required.

Planning and conducting

Planning will help you to come up with well-constructed investigations to answer scientific questions. A well-planned investigation should use appropriate scientific equipment, allow you to gather and record **data** precisely, and be reproducible. This allows you to safely and **ethically** conduct the investigation by following your plan. (See Section 1.7 on p. 18 for more information on the importance of ethics in science.)

Step 1 I can identify equipment required for scientific investigations

When planning an investigation, you need to select the pieces of equipment to suit your purpose. As well as listing the equipment you will need to conduct the investigation, you need to ask yourself what the investigation will measure.

For example, if you are trying to measure the distance a toy car will travel in an investigation, you will need a toy car, and a ruler or a tape measure. For time measurements, you may need a stopwatch, while temperature measurements would require a thermometer.

Go to the 'Laboratory equipment' section on page 279 to see some basic equipment illustrated.

Figure S2.7: When we perform investigations, we can measure temperature change using a thermometer. Here, two students monitor the temperature of an oil bath used to heat a reaction vessel.

Step 2 I can describe ways to minimise risks for a range of investigations

When conducting investigations, we must be able to identify **hazards**. To do this, you should look at the equipment you will use for your investigation and ask how it could cause harm, and describe how this risk of harm could be reduced. For example, see Investigation 1.6, 'Using a Bunsen burner' (page 285), where the following equipment is used:

- safety glasses
- thermometer clamp
- box of matches
- 200 mL measuring cylinder
- gauze mat.
- retort stand
- gas tap
- 500 mL tap water
- tripod
- Bunsen burner
- thermometer
- 250 mL beaker
- stopwatch

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 wearing a laboratory coat.
- The boiling water could injure someone's eye if it splashes. I can reduce this risk by making sure we all wear safety glasses.
- Someone could slip if 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 do not 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.

Risks you describe when planning an investigation can be structured in a table like Table S2.3. This shows us what we need to do in the investigation to reduce the risk of injury. By following the steps in the table, we are implementing the safe practices we have identified and reducing the risk for everyone.

Table S2.3: Reducing risks of injury when using a Bunsen burner

Hazard	Risk	Strategy
Bunsen burner	High likelihood of burns from flame if it contacts the skin or hair	• Place Bunsen burner in the middle of the laboratory bench and away from hands. • Always have Bunsen burner on yellow safety flame when not in use. • Wear laboratory coat and tie back long hair.
Boiling water	High likelihood of eye damage if it splashes into the eye	• Stand away from the beaker of water while it is boiling. • Wear safety glasses to create a barrier between the water and the eyes.
Glass beaker and measuring cylinder	Very high likelihood of cuts if glassware breaks	• Never run while carrying glassware. • Carry glass with two hands. • Place glassware away from the edge of the laboratory bench to prevent it from being knocked onto the floor.

Step 3 I can distinguish between variables to be changed, measured and controlled in an investigation

When planning an investigation, you need to be able to determine the independent variable that will be changed, the dependent variable that will be measured and all the controlled variables (the factors that must be kept the same). If anything changes other than the independent and dependent variables, it is not a fair test and the results will not be valid. You can determine your variables by asking the following questions:

- What am I trying to investigate?
- What one factor should I change?
- What one factor should I measure?
- What factors will I need to control?

Figure S2.8: A salt-water investigation – what will you change and what will you measure?

For example, imagine you are conducting a first-hand investigation to separate salt from a salt-water mixture and wonder if the amount of salt will affect the time it takes.

- *What am I trying to investigate?*
  How does the amount of salt in a salt-water mixture affect the time it takes to be separated?
- *What one factor should I change?*
  I can see from the question that the amount of salt will need to be changed – this will be my *independent variable.*
- *What one factor should I measure?*
  The question asks if the time will be different, so I should measure the time taken to separate the salt – this will be my *dependent variable.*
- *What factors will I need to control?*
  To separate the salt, I will crystallise it by boiling away the water. So, each time, I should use the same:
  - amount of salt water
  - basin to evaporate the salt
  - stopwatch to record the time
  - Bunsen burner with blue flame.

  These will be my *controlled* variables.

Figure S2.9: Our aim shows us the purpose of our investigation. Here, we are investigating the link between the slope of a surface and how far a toy car can travel.

Step 4 I can generate and record data with precision, using digital tools as appropriate

As well as being safe, the data you collect in your investigations must also be recorded with **precision**. To check you are being precise in your measurements, you must ensure the following:

- A results table is constructed to record data from the independent and dependent variables of the investigation.
- The equipment used is appropriate for what you are testing (including using digital equipment where necessary).

You can use a checklist to help you confirm that your data is generated and recorded precisely. Your precise data-recording checklist might include:

- I constructed a results table that allows me to record data about the independent and dependent variables.
- I chose specific scientific equipment that allows me to record data precisely.
- I checked whether digital equipment was available to measure my variables.

Step 5 I can design and conduct reproducible investigations that consider safety, ethical and procedural factors

Before conducting an investigation, you will need to construct a plan so that you know what you are going to do. Plans are written in the form of scientific methods. They should be written as a series of numbered steps. They should also be written in the *third person.* Do not use *I*, *we* or *you*.)

In addition, your investigation should include:

- the *independent and dependent variables* and how you will measure them
- the *controlled variables* and how you will keep them the same
- evidence of *repetition*
- a way to *record the results.*

As an example, imagine we are investigating the following question:

Does the force a toy car is pushed with affect how far it travels across a flat surface?

Our method or procedure would follow the process below:

1. Collect all equipment.
2. Find a flat surface and place a line of tape down to mark the starting point of the car.
3. Place the car level with the starting line.
4. Gently push the car so that it starts to move.
5. Let the car travel along the surface until it comes to a stop.
6. Measure the distance the car travels from the starting line in centimetres, using a tape measure.
7. Record the distance in a results table.
8. Return the car to the starting line.
9. Repeat steps 3 to 8 two more times, applying the same force to the car.
10. Repeat steps 3 to 8 while applying medium and then firm force to the car to start its movement.

Having detailed steps in your method will make it reproducible; that is, it can be conducted by other scientists using the same method that you have used.

When conducting your method, you need to complete all parts of each step before moving onto the next one. So, for the first step of your investigation, you would collect all of the equipment you are going to need. While conducting your investigation, it is important that you are safe and your methods are ethical, so that your data can be trusted.

Figure S2.10: We are studying whether the force applied affects how far a toy car will travel along a flat surface.

To check that your design is safe and ethical, ensure that:

- you or your teacher has conducted an appropriate risk assessment for the investigation
- the investigation is conducted honestly; no one has tried to skew the test or measurement to obtain a certain result
- the data is recorded exactly as measured.

You can use a checklist to confirm that your investigation is safe and ethical.

- I made a risk assessment that identifies at least three hazards and how to prevent them from happening.
- I conducted the investigation exactly as it was written in the method.
- I recorded the data I collected exactly as measured in a results table.

Processing, modelling and analysing

Information generated during a scientific investigation should be recorded in an organised way so that you can process it or use it to model an idea. Processing data involves presenting information in a way that clearly displays what you have found. This sometimes involves using models to show information in a different way to help make sense of it. Once data is processed or modelled, it should be analysed. Analysing data is like being a detective for numbers – uncovering the 'clues' told by the trends and patterns that emerge in the investigation data. This multilayered skill enables people to make sense of the data, make informed decisions, solve problems and predict future trends.

Step 1 I can identify data from tables and graphs

The first step in processing data is simply to recognise data that has already been organised into graphs or tables. When information is on display, you need to read what is presented carefully. Start with the title. What does it tell you? Then move onto headings and units. Ask yourself, what type of information am I looking at? And, what does the data tell me?

Table S2.4 is organised in a way that clearly displays information. From the title, we can recognise that the data will show us how plant growth is affected by sunlight. The headings indicate that measurements were taken in millimetres, and the values in the table show the growth of the plants in various amounts of sunlight.

Table S2.4: Effect of sunlight on plant growth

Plant and environment	Initial plant height (mm)	Growth after 1 week (mm)	Growth after 2 weeks (mm)	Growth after 3 weeks (mm)
Plant 1: no sunlight	181	0	–1	–3
Plant 2: indirect sunlight	175	1	2	4
Plant 3: direct sunlight	178	2	3	5

Step 2 I can organise and display data using tables, keys and/or models

Once you are comfortable recognising information from a table or graph that already contains data, you can use and even construct your own table to record data for a particular investigation using the following instructions.

a **Identify the independent and dependent variables.** Use these to write a descriptive title for the table. The descriptions representing the independent variable are listed in the left column and the dependent variable in the other columns. For example, in Table S2.4 we list the plants and how much sunlight they receive down the left column (independent variable). Then we have three headings for measurements at different times at the top of the other columns (dependent variable).

b **Determine how many rows and columns are required to construct the table.** The number of **datasets** indicates the number of rows required (plus one row for headings). In Table S2.4, we have three datasets: one for each of plants 1, 2 and 3. The number of columns depends on how many times you choose to take measurements. This could be based on time intervals, different items to measure or the number of trials you conduct. The example above uses weekly time intervals across three weeks, including the initial height. Units should be included in the headings when the data is a form of measurement; for example, (cm) or (mL).

c **Construct a table with the appropriate number of rows and columns.** Ensure they are evenly spaced and that there is enough room to write the information clearly.

d **Write headings to represent the variables.** The left column includes the plant number, as well as the specific plant environment. Ensure your headings give the reader a clear picture of the data collected, including the units of measurement used.

Figure S2.11: Because plants grow slowly, it makes sense for you to measure in millimetres (mm) over three weeks.

The following example shows how to construct a table based on the investigation question:

How does the type of wheel – bottle cap, compact disc (CD) or washer – affect the distance travelled by a model car?

a Identify the independent and dependent variables. Use these to write a descriptive title for the table.

*The independent variable is the type of wheel, because this is the thing that changes. We will measure the distance travelled, so that is the dependent variable. A good title is '**Effect of wheel type on distance travelled**'.*

b Determine how many rows and columns you need.

There are three types of wheels, so there will need to be three rows for recording data, plus heading rows. We can measure distance in centimetres (cm). We won't measure the time it takes. We think it is best to run three trials and then determine an average distance. One column is required for each trial, as well as one for the average, plus one for the wheel types.

c Construct a table with the appropriate number of rows and columns.

d Write headings to represent the variables. Remember: the independent variable belongs in the left column and the dependent variable goes along the top, with its unit of measurement.

Now you are ready to conduct the investigation and to record the data in an organised way, as shown in Table S2.5.

Table S2.5: Effect of wheel type on distance travelled

Wheel type	Distance travelled (cm)			
	Trial 1	Trial 2	Trial 3	Average
Bottle cap	11	9	13	(11 + 9 + 13) ÷ 3 = 11
CD	33	31	35	33
Washer	26	20	32	26

Note that in the cells where we show the averages, we only show the process for calculating the average once. For more information, go to the 'Calculating averages' section on page 265.

Step 3 I can process data by using mathematical relationships and/or constructing graphs

The next step is to process your data and show it in a graph. Sometimes you will complete calculations, like determining averages as shown in Table S2.5, which are then graphed instead of the **raw data** points. This allows you to show mathematical relationships in the data. Graphs are useful for displaying data, as they can be easier to understand and interpret. The three graphs we will use most often in science are the column graph, the line graph and the scatter plot, shown in Figure S2.12.

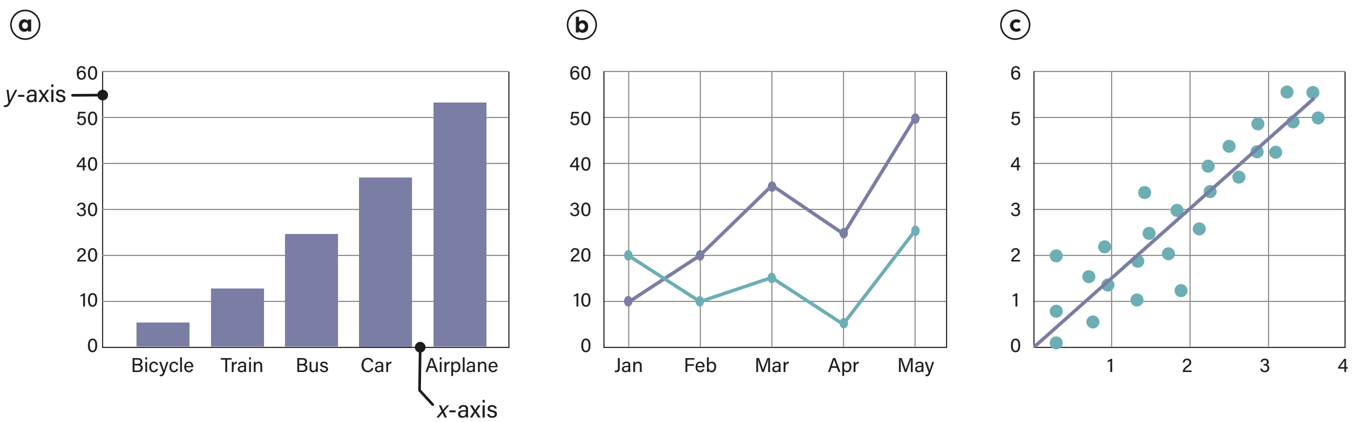


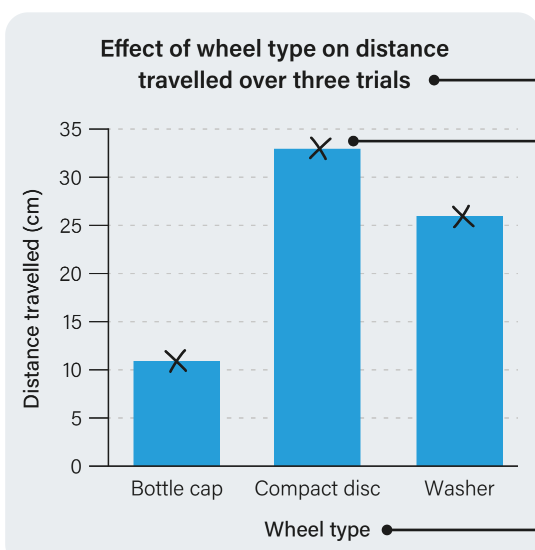
Figure S2.12: Three types of graph used in science: (a) a column graph showing the *x*- and *y*-axes; (b) a line graph; (c) a scatter plot, with a 'line of best fit' running through the middle

Figure S2.13 is a column graph of the results of the model car investigation. The annotation describes how to construct the graph.

(a) Determine the range of the axes based on the data you have collected.

Write the dependent variable on the *y*-axis (vertical axis) and the independent variable on the *x*-axis (the horizontal axis).

Plot the measurements along the *y*-axis and the wheel type along the *x*-axis. The lowest data value from our averages is 11. The range of the *y*-axis must begin below this value. We could choose 10, 5 or 0, but it is good to start at 0 for simplicity. The largest data value is 33, so the highest value on the *y*-axis must be higher than that, such as 35.



(c) Write the title, label the axes and plot your points on the graph – the graph title can be the same as the title of your table. Be sure to include the independent and dependent variables, not only in the title but also on the axes labels. Include the unit of measurement, if needed, on each axis label.

(d) Draw your graph – a column graph requires you to draw and shade the columns. (A line graph means you connect the points in a line, while a scatter plot graph requires you to draw a 'line of best fit' that represents an average of your points.)

(b) Use a ruler to draw the axes and select the space between values. Since the *y*-axis will be spread from 0 to 35, it makes sense to count by fives up the axis. Avoid writing every number between 1 and 35, as this will make the graph too cluttered.

Figure S2.13: A column graph of the results of a model car investigation

Categories of factors like the wheel type are best represented in a column graph, as shown in Figure S2.14. If measuring continuous time is involved, a line graph with connected points is best. If both the independent and dependent variable values are numbers, a scatter plot is best. A scatter plot includes a 'line of best fit', to show the **trend**.

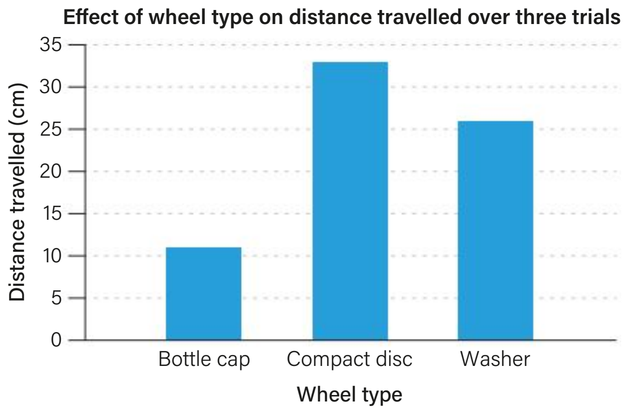


Figure S2.14: An example of a column graph using data from Table S2.5

Step 4 I can identify and discuss trends and/or patterns in a range of dataset representations

A trend is shown by the line or bars in your graph moving in a general direction, usually up or down, as shown in Figure S2.15. A **pattern** is when the data repeats in predictable ways. Sometimes your data has no clear trend, so your visualisation will show random values all over, or there may be a sideways trend (a horizontal line).

Figure S2.15: The green line is trending up, while the red line is trending down.

Figure S2.16 is a graph of snake sightings. It does not show a trend across the whole year. It shows a trend downwards from January to June and a trend upwards from July to December.

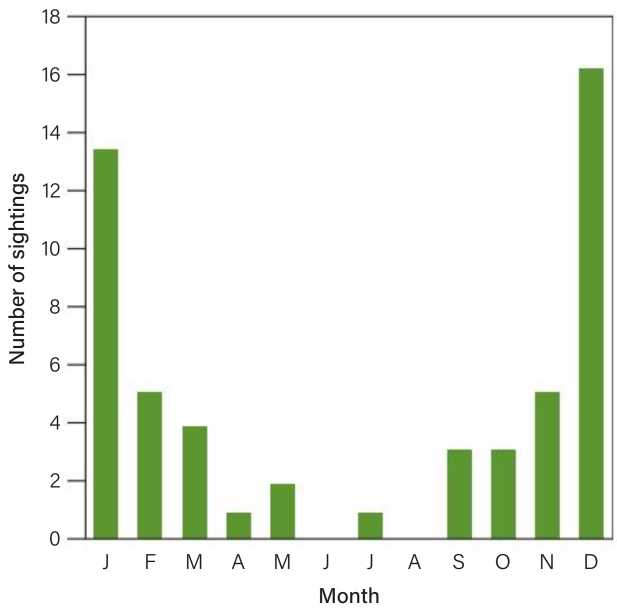


Figure S2.16: Snake sightings, average per month

To recognise patterns, look for recurring values or repeating shapes. For example, Figure S2.16 does not show a year-wide trend, so the next thing you look for is a pattern. It is clear that there are more snake sightings in the warmer months, and not many at all in winter. This is a pattern that we would expect to see year after year.

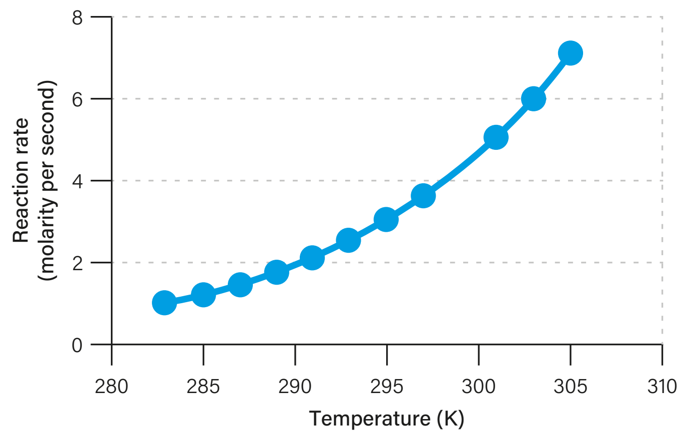
It is clear that the pattern in Figure S2.16 is that snake sightings trend downwards in the first half of the year and upwards in the second half. The trends alternate in a repeating pattern each year.

Figure S2.17: The number of snake sightings increases with average temperature across the year.

Next, we have to link any trends to the variables of the investigation. The relationship between the variables in an investigation is called the **correlation**. Identifying the correlation enables you to then describe the relationship between the dependent and independent variables.

- *Positive correlation:* the relationship between variables is direct. This means that if the value of one variable increases, the value of the other variable also increases, and vice versa.

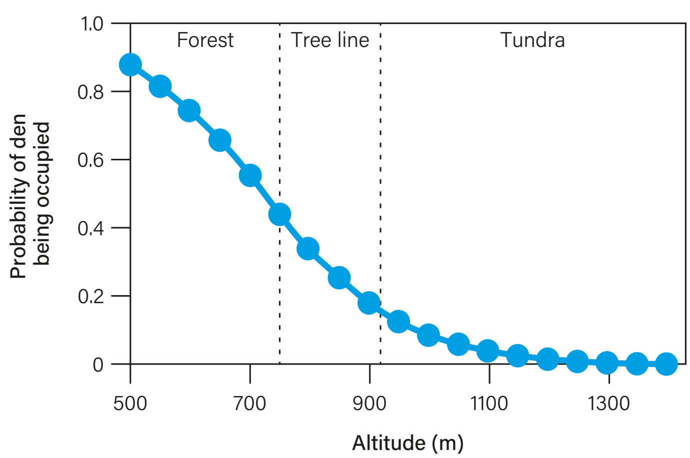
Figure S2.18: A line graph of reaction rates in an investigation, showing a positive correlation



This graph shows a positive correlation. As temperature increases, so does the rate of the chemical reaction. The relationship between temperature and rate of reaction is direct.

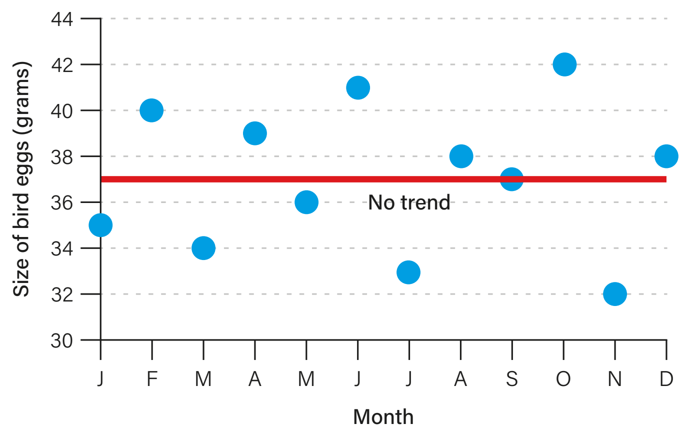
- *Negative correlation:* the relationship between variables is indirect. This means that if the value of one variable changes in one direction, the value of the other variable does the opposite.

Figure S2.19: A line graph of fox den occupation rates, showing a negative correlation



This graph shows a negative correlation. The likelihood of the fox den being occupied decreases as the altitude of the habitat increases. If one goes up, the other goes down. This displays an indirect relationship between whether a den is occupied and its altitude.

- *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 whether bird eggs will be heavier in a particular month because the data does not show a pattern or trend.

Figure S2.20: A graph of the mass of bird eggs and month laid

Once patterns and trends are identified, datasets can be represented in numerous other formats. You should choose an appropriate representation of your information, just like picking the right tool for a job. Figures S2.21 to S2.25 show some ways you can visually communicate the information.

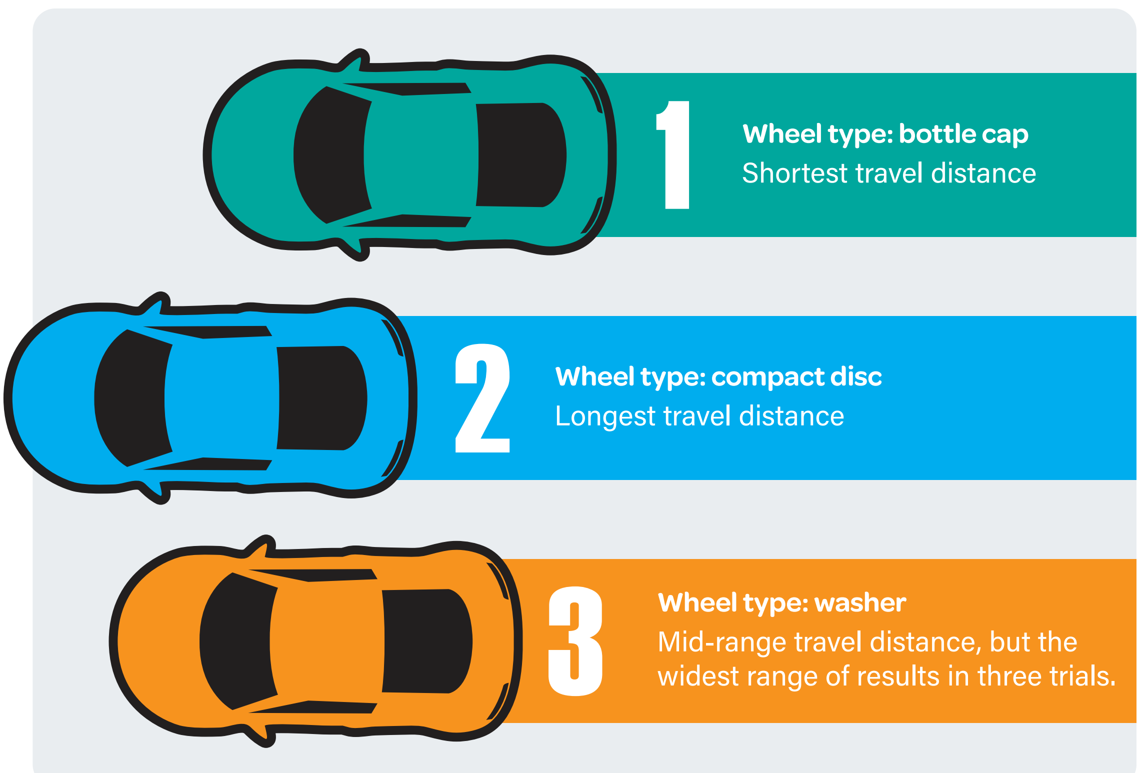


Figure S2.21: An infographic showing the results of the model car investigation from step 3

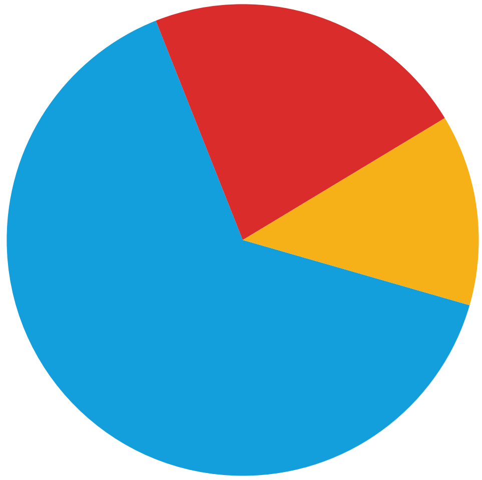


Figure S2.22:
A pie chart is best for looking at the parts that make up a whole.

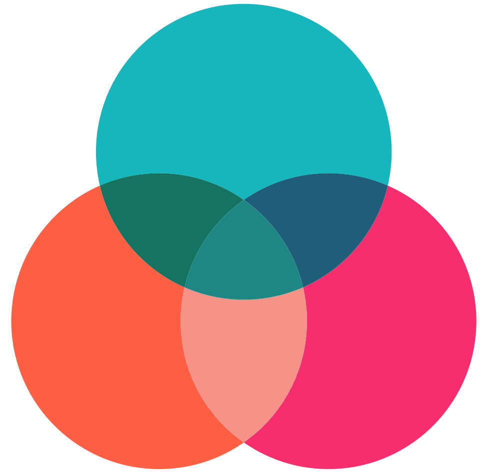


Figure S2.23:
A Venn diagram is used to compare similarities and differences.

Figure S2.24: A word cloud showing the magnitude of results of the car investigation from step 3

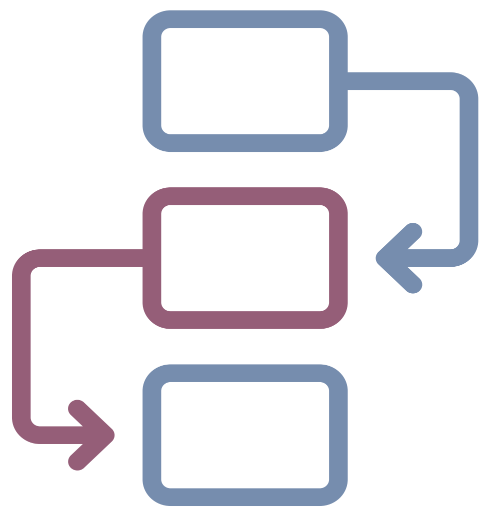


Figure S2.25: A flow diagram can be used to show how one thing moves or transforms to another.

Step 5 I can analyse processed data for patterns, trends, relationships and anomalies

Trends and patterns across datasets in conjunction with scientific knowledge can be used to identify relationships between variables. We can then ask: Why is one variable affected by another variable in this way? The analysis of trends, patterns and relationships leads to scientific findings and conclusions.

For example, in Figure S2.19 the negative correlation between the fox den being occupied and altitude is linked to habitat theory and the effect of altitude on living conditions for the fox. As altitude increases, temperature and access to food decreases. These are reasons for why the den is less likely to be occupied at high altitudes, especially in winter.

Often, the information used to explain relationships between variables is aligned with the information used to inform predictions made at the start of an investigation.

As scientists, we can identify scientific findings based on the data that emerges from an investigation or study by:

a stating the relationship between the specific variables, based on the data.

This finding can then be generalised by:

b replacing the terms specific to the investigation with general terminology, so it can be applied in a variety of contexts.

For example, if you investigate the effects of friction on the time it takes an object to reach the bottom of a ramp, you could use a toy car as the object, and ramp surfaces with varying amounts of friction, such as glass and wood. The results would show that the car reaches the bottom more quickly when rolled down the glass ramp than the wooden ramp. You can then use the points above to identify a finding.

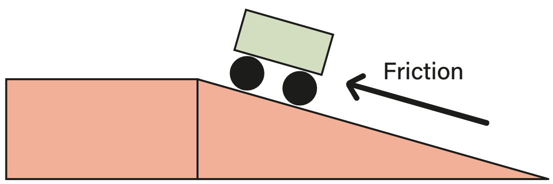


Figure S2.26: Investigating the effects of friction

a State the relationship between the specific variables, based on the data.

When the car rolls down the wooden ramp with more friction, it stops sooner than when it rolls down the glass ramp with less friction.

b Replace the terms specific to the investigation with general terminology so the statement can be applied in a variety of contexts.

When an object slides across a surface with more friction, it will come to a stop sooner than when it slides over a surface with less friction.

From the results, we analysed the trends and relationships in order to identify the finding and state the conclusion of the investigation. The term *car* was replaced with *object*, and instead of stating the specific surface used in the experiment, we generalised to the amount of friction – more or less. Table S2.6 provides some more examples of drawing conclusions.

Table S2.6: Converting investigation results into broader conclusions

Scientific finding	Conclusion
When carbon dioxide gas from a chemical reaction is captured in a balloon and then heated in a hot-water bath, the size of the balloon increases.	When the temperature of gas particles increases, the volume of the substance expands.
As the number of trees planted in eucalypt forests increases, the population of ring-tailed possums also increases.	Revegetation efforts increase native animal populations by restoring natural habitats.
The more water a barrel contains, the greater the number of people required to push it 2 metres.	The greater the mass of an object, the more force is required to move it from a stationary position.

This does not mean that all our conclusions are correct. It is simply an opportunity to say what we know at that time and to investigate further.

Sometimes **data points** and conclusions do not follow the observed trend in a dataset or the expected outcome of an investigation. These are called outliers or **anomalies** and must be further analysed to determine whether the deviation is due to either an error in how the data was collected or to genuinely new discoveries. If they are mistakes or errors, they should not be averaged into the results. If it is unclear why there are anomalies, further investigations are required.

Evaluating

Evaluating investigations and conclusions is a bit like playing the role of a scientific inspector; it is about quality control! It involves carefully reviewing how the data was collected to determine whether the results are accurate and really do represent what they are supposed to measure. How close are the results to the true value? How valid is the investigation? Can the results be justified? Is there any conflicting evidence or unanswered questions? How can we make improvements? Work your way up the Learning Ladder to approach this skill effectively.

Step 1 I can identify errors and assumptions in an investigation

In any investigation, our aim is to collect data that is accurate and valid. In other words, we want our results to find the **true value** that answers the experimental question by conducting a **fair test**. It is up to us, the investigators, to identify sources of errors that lower the **accuracy** and validity of the results. Ask yourself the following questions to reveal problems with the investigation:

1. Was my experimental set-up or process different from the intended procedure?
2. Did I record any qualitative observations related to difficulties or assumptions in the method?
3. Were there any new variables identified during the investigation that I had not controlled?
4. Did anything unexpected occur during the investigation, including strange results?

If you answered 'YES' to any of the above questions, you have just revealed sources of errors. In most cases, errors are due to controlled variables that were not controlled properly.

Let's consider the investigation question:

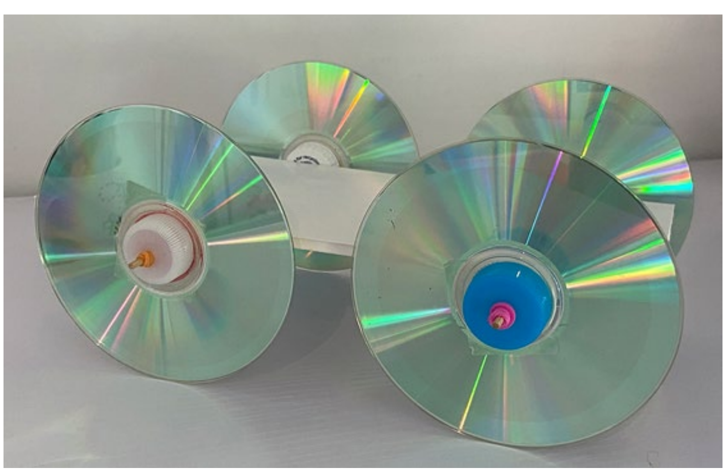
How does the type of wheel (bottle cap, CD, washer) affect the distance travelled by a model car?

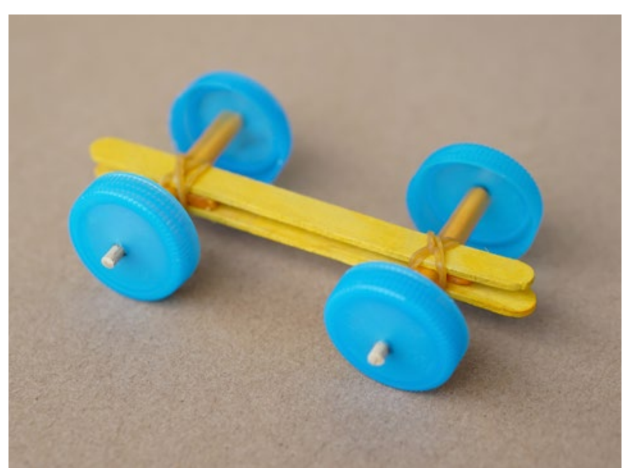
Table S2.7 elaborates on how answering 'YES' to each question can lead to the identification of errors. Each of the errors identified reduces the accuracy and/or validity of the results.

Table S2.7: Identifying the sources of errors

Questions to reveal errors	Describing the scenario	Source of error
1 Did your experimental set-up or process differ from the intended procedure?	*The method required the ramp to be propped up on a printer box, but there was only one box. To save time, different things were used to prop up the ramp for each car. This method went against the intended procedure.*	*Different ramp angles were used for each car.*
2 Did you record any qualitative observations related to difficulties or assumptions in the method?	*The cars did not always move in a straight line, which caused variations in how the distance was recorded. If it went straight, the total path of the car was measured, but if it curved, the distance from the starting line to the stopping point was measured directly. This shows that assumptions were made about the path and distance the cars travelled.*	*The way the distance was measured was not consistent for all three cars.*
3 Were there any new variables identified during the investigation that were not controlled?	*The type of wheel was the independent variable for this investigation, but it is not clear whether the material type or the size of the wheel is responsible for the results.*	*The material AND size of the wheels differed, which means there is more than one independent variable.*
4 Did anything unexpected occur during the investigation, including strange results?	*During the third trial for the car with washer wheels, a gust of wind came through the classroom. Interestingly, the car in this trial went the furthest by far, as compared to the other two trials.*	*The surrounding environment was not kept constant for all trials, (e.g the gust of wind that passed through the classroom in one trial).*
	For some trials, the student pushed the car down the ramp instead of letting it roll on its own as the method indicated.	*The force applied to the cars was not consistent across all three trials.*

Figure S2.27: We can see that different-sized wheels were used in this experiment; therefore, this is a source of error in the results.





Step 2 I can describe different types of errors in an investigation method

There are different types of errors that you may encounter in an investigation. Being able to identify and describe the types of errors present will help you to understand how they have impacted on your data. Table S2.8 summarises the different types of errors you will be expected to recognise.

Table S2.8: Types of errors

Type of error	Description
Random	Unpredictable differences in how measurements are taken, resulting in a 'random' variation of values.
Systematic	A consistent difference in measurement from the true value. When a particular value is measured repeatedly, the error is the same.
Personal	Mistakes that can be avoided if the method is followed correctly. Rather than discussing personal errors in a report, the method should be repeated to eliminate mistakes.

Table S2.9 considers the sources of error identified in step 1 and determines their type.

Table S2.9: Types of sources of error identified in step 1

Source of error	Type of error	Supporting information
Different ramp angles were used for each car.	Systematic	*If two ramps had the standard angle but the ramp for the CD car had a higher angle, the CD car would experience more force down the ramp, leading to a greater distance travelled than if it had gone down the standard ramp. The additional distance travelled would be relatively the same for every trial for that car.*
The way the distance was measured was not consistent for all three cars.	Random	*The method did not specify how to measure the distance travelled; therefore, it may have been done differently across all cars and trials. There is no way to know how much or in what direction the values vary from the true values.*
The surrounding environment was not kept constant for all trials (e.g. the gust of wind that passed through the classroom in one trial).	Random	*External factors may have influenced the cars' performance down the ramp for better or worse, but there is no way to know the extent of the impact.*
The force applied to the cars was not consistent across all three trials due to some students pushing the car at the start.	Personal	*This mistake can be avoided if the method is followed correctly. If it is not possible to redo the investigation, this would be considered a random error as you have no way to know the impact of the mistake. Ideally, the trials where the cars were pushed should be eliminated from the data and redone.*

Step 3 I can support investigation findings with evidence-based explanations

Once you understand the difference between various types of errors and their sources, the next step is to support the investigation findings with evidence-based explanations of how the errors affect your data. It is not enough simply to say that an error will reduce the accuracy or validity of results. This is assumed in step 1 of the Learning Ladder. At step 3, you are expected to discuss specifically HOW the error affects your investigation findings. Does it increase the experimental value? Why, and by how much? This is the evidence required to support your findings.

Random and systematic errors each have a known impact on the data, as Table S2.10 illustrates.

Table S2.10: Known impacts on data of random and systematic errors

Error type and impact	Elaboration
Random errors **reduce precision**  *Values are spread around the centre true value	*Each data value is not accurate; however, the average of all values is often close to the true value. Therefore, random errors do not necessarily affect the accuracy of an experiment, as long as there are enough trials to average out the error.*
Systematic errors **reduce accuracy**  *Values are close to each other but not to the true value	*Data values are precise but not accurate, because the collection of data is affected in a predictable and consistent way. For example, an uncalibrated scale used to measure mass might add 1 gram to all measurements.*
Personal errors can **reduce precision and/or accuracy**	*Mistakes can be random errors or systematic errors, depending on whether the impact on the data varies or is consistently predictable. Refer to step 2 for more information.*

To effectively support your findings with evidence-based explanations about the quality of your data, you must first determine the type of error present and its general impact, as outlined above. This is the first item on the checklist below.

CHECKLIST FOR SUPPORTING FINDINGS WITH EVIDENCE-BASED EXPLANATIONS

- ☐ Determines the type of error and its impact on the data; reduces precision and/or reduces accuracy
- ☐ Compares experimental values to the true values, where possible, referenced in scientific literature (see the 'Conducting scientific research' section on page 256)
- ☐ Uses descriptive words to describe the impact on data (higher, lower, heavier, stronger, shorter, etc.)
- ☐ Makes links between the quality of data and the accuracy and/or validity of the results

Use the checklist to ensure your explanation includes everything necessary for you to display your skills at step 3 of the Learning Ladder.

Let us now revisit a couple of the errors from the previous step to see how they can be explained with reference to the quality of data (see Table S2.11).

Table S2.11: Evidence-based explanations of possible sources of error

Source of error	Evidence-based explanations to support findings
Different ramp angles were used for each car (systematic).	The distance travelled for the CD car (higher angle ramp) is greater than it would have been on a standard ramp as supported by forces theory in Chapter 8. This increases all values recorded for the CD car by the same amount, reducing the accuracy of the average of the trials for this car. This, in turn, reduces the validity of the results as we cannot be sure if the CD would have gone further than the other cars had it been done on a standard ramp.
The way the distance was measured was not consistent for all three cars (random).	As a result of inconsistent measuring, the precision of data values is reduced. There is no way to know how much or in what direction each value differs from the true values. Because there were three trials for each car, the average of all three trials is closer to the true value than a single data value on its own. Averaging trial values improves the quality of the data and, as a result, increases the accuracy of the results.

*The text colour coincides with the checklist items on the opposite page.

Please keep in mind that there may be several correct ways to use evidence-based explanations to support investigation findings. The more practice you have, and the more feedback you get from your teacher, the more comfortable you will become with using this skill.

Step 4 I can construct evidence-based arguments to justify conclusions, address ethical issues or evaluate claims

Now that you know how to support investigation findings with reference to errors and assumptions, the next step is to construct evidence-based arguments to discuss a variety of factors involved in first- and second-hand investigations. This includes things related to the quality of data collected, as outlined in step 3, but also whether ethical factors have been considered (see Section 1.7 in Chapter 1).

For help with writing an evidence-based scientific argument, see the 'Scientific writing' section on page 249. Now, combine your explanations from step 3 and/or your analysis of whether ethical considerations have been made appropriately, and construct your argument.

Step 5 I can evaluate conclusions and claims with reference to conflicting evidence and unanswered questions

It is important to be cautious when reading and utilising second-hand data and information. There are times when evidence within an investigation report or across multiple studies is conflicting. For example, one investigation might indicate that drinking a soft drink before you run a race will help you to run faster, while another might suggest that it slows you down. In situations like this, evaluating the claims can help you to verify which source is more or less accurate in its findings. Maybe the first investigation used faster runners, indicating that the variables may not have been properly controlled.

There are also sometimes unanswered questions that should be considered when evaluating conclusions and claims. For instance, what type of soft drink was used in the investigation: regular, sugar-free, caffeine-free? And was it opened right before the test? From a bottle or a can? If these things are not specified in the investigation report, they become questions that need to be answered before the claims can be properly evaluated.

If conflicting evidence and/or unanswered questions persist within and across investigation reports, a formal evaluation should make reference to these factors. Further research would be required before the conclusions or claims can be justified.

Use the checklist below to evaluate the conclusions and claims of an investigation.

CHECKLIST FOR EVALUATING CONCLUSIONS AND CLAIMS

- [ ] One variable was changed.
- [ ] One variable was measured.
- [ ] All other variables were properly controlled, without any assumptions.
- [ ] Any variables that were not well controlled are acknowledged and discussed in the investigation report.
- [ ] Any safety and/or ethical considerations have been considered.
- [ ] No other reliable sources present evidence that conflicts with the claims made.
- [ ] There are no unanswered questions related to the results that support the findings.

Ticking each of the items in the checklist does not guarantee that the conclusions or claims are fully justified. Nor do all items need to be ticked in order for a claim to be true. The checklist is just a guide to help us evaluate a variety of scientific claims by asking standard questions as a starting point. More questions can always be asked and further studies carried out to help us continue to contribute to the scientific body of knowledge in safe, thorough and ethical ways.

Communicating

Communicating is essential to science – scientists need to share the ideas they have and the findings they have discovered. When we communicate, we need to consider what we are trying to say, and who we are trying to say it to. This allows us to present our ideas and findings using specific methods and language targeted to our particular audience.

Step 1 I can identify scientific terminology used to communicate information

In science, specific scientific terminology is used to communicate findings or ideas to other scientists. Scientific terminology can help us to describe specific features or qualities, and allow us to communicate information from a first-hand investigation.

To recognise scientific terminology, you need to consider the following:

- Do the words used provide information about the science behind this idea or concept?
- Are the words specific and used correctly in context?

For example, if we want to identify scientific terminology related to the quokka, we can study the following passage:

The quokka (Setonix brachyurus) is a mammal that is part of the same family as the kangaroo and the wallaby, and part of kingdom Animalia. Quokkas are herbivores, living off native shrubs and grasses on Rottnest Island in Western Australia. Quokkas are currently listed as a 'vulnerable' species, because they are eaten by predators, usually introduced species such as cats.

The passage describes part of the classification of the quokka, as well as its diet, habitat and predators. Specific classification and biology terms are used, and they correctly describe the quokka from a scientific perspective. This allows us to identify that the passage contains specific scientific terminology.

Figure S2.28: Describing the features of a quokka helped scientists to classify it.

Step 2 I can select appropriate formats to communicate ideas and findings

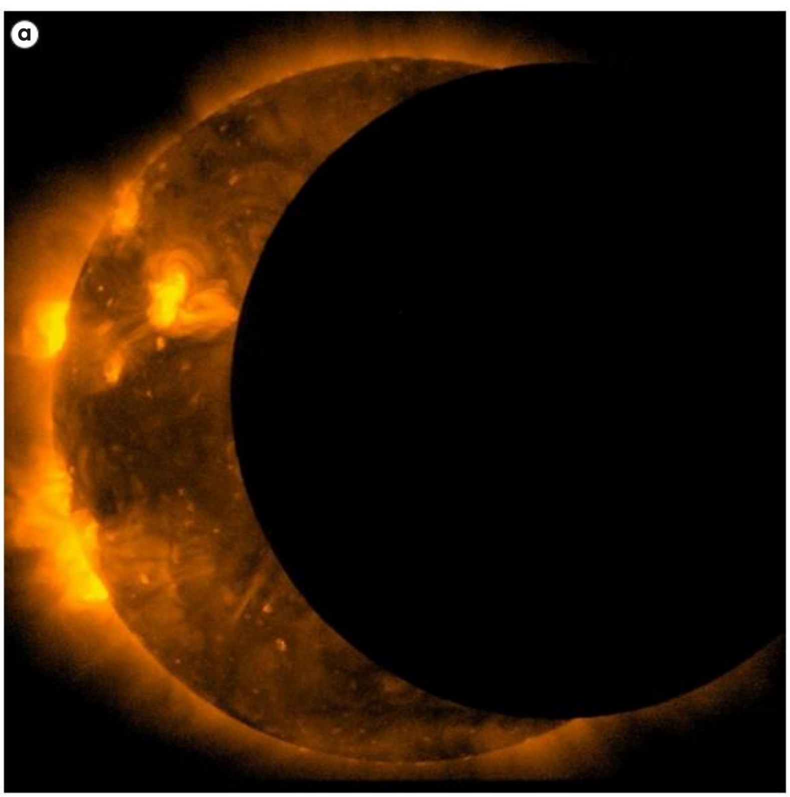
You can communicate your scientific findings in many different ways. To decide on a suitable method of communication, ask the following questions:

- What information do I have?
- What do I want to communicate to the audience?
- What format will display this information most clearly?

Table S2.12 shows some examples of how to apply these questions to make your decision.

Table S2.12: Choosing formats for scientific communication

Information	Communication goal	Format
Data from a first-hand investigation	What I found out while investigating a scientific question	Scientific table or graph
A complete first-hand investigation	How I did the investigation and what the results of the investigation were	Scientific report
What causes an eclipse	How the movement of the Sun, Earth and Moon cause an eclipse	Scientific poster with text and diagrams
Water movement	How water moves through the different stages of the water cycle	Scientific diagram with labels
Bacteria structure	What a bacteria cell looks like and contains	Scientific model



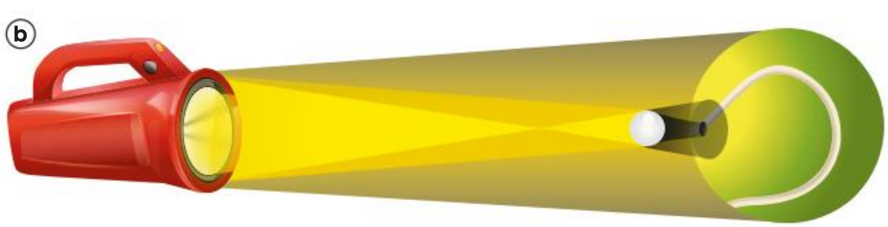


Figure S2.29: (a) A solar eclipse; (b) how it could be modelled to scientifically communicate what causes this phenomenon

Step 3 I can prepare a variety of representations to communicate ideas and findings

After selecting a method of communication, and a format to present it, you can then look at how to construct a presentation. When considering how to present scientific information in a chosen format, you can ask the following questions:

- What is the main point I want to get across?
- What information do I need to include in this format?
- What is the best way to present this information in my chosen format?

Once you have answered these questions, you can start to put your information into your selected format. Make sure you are using correct scientific terminology and information relating to your topic. More detailed examples of how to construct each type of presentation can be found in the 'Scientific writing' section on page 249.

Step 4 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 S2.13 provides a range of examples.

Table S2.13: Digital presentation formats

Information	Presentation format	Example communication presentation method
Data from a first-hand investigation	Scientific table or graph	Google Sheets or Microsoft Excel
A complete first-hand investigation	Scientific report	Google document or Microsoft Word document, with typed information
What causes an eclipse	Scientific poster with text and diagrams	Canva or slides to visually present information
Water movement	Scientific diagrams with labels	Canva, slides or Lucidchart software to create a diagram with labels
Bacteria structure	Scientific model	Canva or Lucidchart software to create two-dimensional models

Figure S2.30: Digital technologies help us to neatly lay out information ready for presenting.

Step 5 I can present scientific findings and arguments for specific purposes to specific audiences

Now that you can determine appropriate communication formats, you should select information and text that matches the audience you are trying to communicate with. To help you figure out *how* to tailor your communication, consider the:

- age of your audience
- knowledge level of your audience
- idea or scientific principle you want to communicate
- best way to tell your audience about this principle.

Table S2.14 shows how the same information can be presented to two different audiences.

Table S2.14: Tailoring your message for different audiences

Age	Knowledge level	Idea	Communication
Eight-year-old children	Very limited	Water as a resource	Summarise the water cycle and encourage household water-saving measures on a poster.
Adults	High – environmental scientists	Water as a resource	Present research on ideas to prevent surface evaporation from lakes and dams as an article or oral presentation.

We can then create a communication format for each audience. For the eight-year-olds, we could include the following text on a simple poster.

In the water cycle, rain falls and then runs off into storage areas like dams and lakes. We use some of this water in our homes. To help us use less water, we can take shorter showers or shallow baths, and turn off taps while cleaning our teeth. These actions mean every household uses less water overall, and this is also known as using water sustainably.

The adult scientists would expect more sophisticated language, and the information could be displayed using specific diagrams and figures.

When water that has precipitated runs off into storage areas such as dams and lakes, it is subject to surface evaporation, reducing the amount available for household consumption. Placing products such as evaporation-reducing shade balls on the surfaces of these areas will assist in minimising surface evaporation, reducing water loss and increasing availability for household usage, even in times of drought.

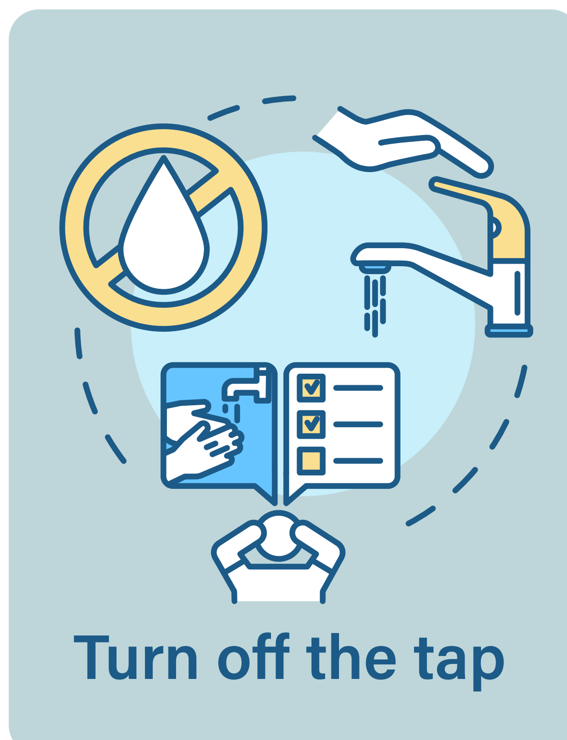


Figure S2.31: A poster showing sustainable water usage in the home would be a suitable communication method to share ideas with younger audiences who have little scientific knowledge.

S3 Scientific writing

'Scientific writing' means applying your writing skills to your science studies to help you develop your understanding and communicate what you have learnt.

Key term

plagiarise: to copy someone else's work and present it as your own

Figure S3.1: Scientific writing is fundamental to science communication.

Table S3.1: Investigation report sections matched to their science inquiry skills

Section	Focused skill	Embedded throughout
Title	Questioning and predicting	Communicating
Introduction ▪ Background ▪ Aim ▪ Hypothesis	Questioning and predicting	
Risk assessment	Planning and conducting	
Materials	Planning and conducting	
Method	Planning and conducting	
Results	Processing, modelling and analysing	
Discussion	Processing, modelling and analysing Evaluating	
Conclusion	Evaluating	
References	Evaluating	

Writing investigation reports

Writing a clear and concise report after your investigation is complete will help other people to understand your work. Table S3.1 provides an overview of the sections that are often included in a standard investigation report, as well as the science inquiry skill used in each section.

Your investigation reports should typically have a similar structure to the one shown below.

The title is clear and uses plain language. Many scientists write their title as a research question.

Set the scene. If there is scientific information or context for the investigation, summarise it here.

The background often leads into the objective of the investigation. Use your research question to write the aim starting with a verb, such as: 'To investigate ...'

If your investigation is an experiment, you should predict what you think will happen based on scientific theory. A good hypothesis will include the independent variable and the predicted effect on the dependent variable.

List all materials and equipment with amounts and sizes as simple bullet points.

The method shows how the investigation was conducted. Number the steps, and write in the past tense and in the third person.

Methods should be written like a recipe – simple, clear and detailed.

How does the amount of direct sunlight affect plant growth?

Introduction

Plants require sunlight to produce their food using photosynthesis. Some plants get direct sunlight, while others get indirect sunlight. It would be interesting to know how different plants are affected by different amounts of sunlight, to help us make decisions about where to put garden beds for certain types of plants.

Aim

To investigate whether the amount of direct sunlight affects growth of a certain species of plant.

Hypothesis

If a plant is placed in direct sunlight, then it will grow more than a plant in indirect or no light, because plants require sunlight to produce food required for growth.

Materials

- *3 plants of the same species and of similar size*
- *250 mL beaker*

Method

1. *Each plant was labelled 1, 2 or 3 and measured to obtain a starting height for each one. The heights were recorded in a simple table.*
2. *Plant 1 was placed in a dark cupboard.*
3. *Plant 2 was placed near a window where it could receive indirect sunlight.*
4. *Plant 3 was placed outside in direct sunlight but sheltered from rain.*
5. *The heights of the plants were measured every week for three weeks and the growth was recorded in the results table.*
6. *The plants were watered the same amount every three days.*

Results

Table 1: *Effect of sunlight on plant growth*

Plant environment	Initial height (mm)	Growth after 1 week (mm)	Growth after 2 weeks (mm)	Growth after 3 weeks (mm)
Plant 1: no sunlight	181	0	–1	–3
Plant 2: indirect sunlight	175	1	2	4
Plant 3: direct sunlight	178	2	3	5

Include recorded data such as the results table. Include any visual elements, such as photos or graphs, here.

Discussion

As the results in Table 1 show, the plant that had the most growth was the plant in direct sunlight (Plant 3). The plant in direct sunlight had the highest growth, with 2 mm after the first week, 3 mm after the second week and 5 mm after the third week, compared to the plant in no sunlight (Plant 1), which had no growth, then shrank and lost growth in weeks 2 and 3. The results make sense because sunlight is crucial in photosynthesis – the process by which plants transform sunlight into usable energy.

One source of error is that two of the plants were inside, and one was outside, which may have had an impact on growth. The method could be improved by requiring all plants to be outside, each with a different amount of shade coverage. There may have also been some errors to do with accurately measuring the plants. The method could be improved by including photos of the plants against the same ruler backdrop, to confirm the accuracy of measurements.

Use the discussion to analyse the results and identify a key finding. Evaluate the method to identify the quality and limitations of the data.

Start by summarising the data, using amounts in your table. Identify any trends or patterns that could lead to your key finding. Link your finding to your scientific understandings.

Identify any potential errors here and suggest improvements to try to control them.

Conclusion

The results of this investigation show that the amount of direct sunlight does impact on the growth of this species of plant. The investigation supported the hypothesis that if this species of plant is put in direct sunlight, it will grow more than a plant of that species in indirect or no light. This is due to more sunlight being available for photosynthesis, which is how plants grow.

Conclude the report by responding to the aim. Mention whether the results supported or refuted your hypothesis. Do not present any new information.

The conclusion can also be the closing paragraph of the discussion.

References

BBC, 2019, 'Photosynthesis', *BBC Bitesize Articles, accessed 10 January 2024, mea.digital/gsnsw4_9_1.*

References show the source of any information you used that was not your own, including for the background.

Presenting scientific information

The ability to choose and create an appropriate presentation format allows you to transform complex ideas into engaging concepts and to share your discoveries in ways that will best reach your audience. Presenting scientific information effectively is a powerful tool that can help shape the future of science.

Posters

The purpose of a scientific poster is to communicate information on a particular topic or to display the findings of an investigation in a quick and engaging way. When information is shared on a poster, it should be easy for people to see the main idea as they are walking past. A display of scientific posters might include dozens of posters lined up, one after another. This is why it is important for your main finding to be the central focus.

A poster includes the same sections as an investigation report. However, each section includes only the most important information. Anyone who wants to learn more about the investigation details can read the full report. Figure S3.2 shows the basic framework for a scientific poster.

Figure S3.2: A simple framework for the structure of a scientific poster

Figure S3.3: A simple scientific poster

Figure S3.3 gives an example of how we might present, in poster form, the findings from an investigation report on plants and sunlight. We could add visual interest by adding photos or illustrations of the plants.

How does the amount of direct sunlight affect plant growth?

Introduction

Plants require sunlight to produce their food using photosynthesis. This investigation aims to explore how the amount of sunlight affects plant growth. It is hypothesised that 'If a plant is placed in direct sunlight, then it will grow more than a plant in indirect or no light.'

Materials & method

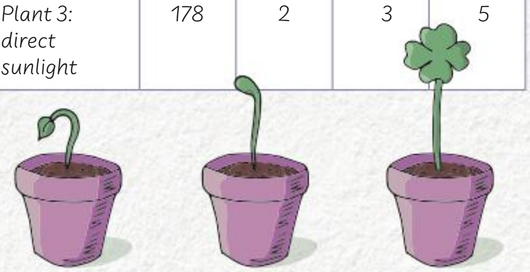
Three plants were placed in different locations: in a dark cupboard, near a window with indirect sunlight, and outside in direct sunlight but sheltered from rain. All the plants were watered the same. Plant height was measured every week for three weeks.

Plants with direct sunlight grow more than plants of the same species with indirect or no light.

Results data

Table 1: Effect of sunlight on plant growth

Plant environment	Initial height (mm)	Growth after 1 week (mm)	Growth after 2 weeks (mm)	Growth after 3 weeks (mm)
Plant 1: no sunlight	181	0	–1	–3
Plant 2: indirect sunlight	175	1	2	4
Plant 3: direct sunlight	178	2	3	5



Discussion

The plant that had the most growth (5 mm) was the plant in direct sunlight. The plant in no sunlight had no growth in week 1, then shrank in weeks 2 and 3. The results make sense because sunlight is crucial in the process by which plants transform sunlight into usable energy – photosynthesis.

One source of error is that two of the plants were inside, and one was outside, which may have had an impact on growth. The method could be improved by requiring all plants to be outside.

Conclusion

The investigation supported the hypothesis that if this species of plant is put in direct sunlight, it will grow more than a plant of that species in indirect or no light.

***Reference:** BBC, 2019, 'Photosynthesis', BBC Bitesize Articles, accessed 10 January 2024, mea.digital/gsnsw4_9_1.*

Articles

The purpose of a scientific article is to communicate the findings of an investigation or to summarise research into secondary sources. A scientific article is divided into specific sections, each with a purpose to communicate specific information relating to the scientific concept being studied.

1 Heading – a relevant title that is a statement of what the article is about
2 Author – the name of the person writing the article
3 Abstract – a summary of what was done or what was found in the study
4 Introduction – some research on and background to the topic, linked to a hypothesis
5 Method – the methods scientists used to investigate the topic
6 Results – the results found about the topic
7 Discussion – a detailed analysis of the results, linked to the background
8 References – a list of your sources. See the 'Referencing' section on page 258 for more information.

Figure S3.5 provides an example framework for a science article.

Figure S3.4: High-quality scientific articles can be reviewed by other scientists and published in scientific journals.

Figure S3.5: The structure of a science article on plant growth

The effect of sunlight on plant growth — Heading

Bailey Chang — Author

Abstract

A review of an investigation into the growth of plants was conducted. The investigation and method were studied and analysed to determine the effect of sunlight on plant growth. The study found that direct exposure to sunlight correlates with increased levels of plant growth. Further investigation into similar studies could assist in supporting this hypothesis. — Abstract

Introduction

Plants require sunlight to produce their food by undergoing photosynthesis (BBC, 2019). The investigation aimed to explore how the amount of sunlight affects plant growth. It was hypothesised that if a plant is placed in direct sunlight, then it will grow more than a plant in indirect or no light, as it will be able to photosynthesise while in the presence of light. — Introduction

Method

Within this investigation, three plants were placed in different locations: in a dark cupboard, near a window with indirect sunlight, and outside in direct sun but sheltered from rain. All the plants were provided the same amount of water. Plant height was measured every week for three weeks. — Method

Results

Discussion

References

Results

It was found that sunlight has a direct impact on plant growth. Table 1 shows the amount of plant growth in different levels of sunlight.

Table 1: Effect of sunlight on plant growth

Plant environment	Initial height (mm)	Growth after 1 week (mm)	Growth after 2 weeks (mm)	Growth after 3 weeks (mm)
Plant 1: no sunlight	181	0	–1	–3
Plant 2: indirect sunlight	175	1	2	4
Plant 3: direct sunlight	178	2	3	5

Discussion

The results show that sunlight exposure had a direct impact on plant growth levels. It was found that the plant in direct sunlight had the most growth (5 mm). The plant in no sunlight had no growth in week 1, then shrank in weeks 2 and 3. The results make sense because sunlight is crucial in the process by which plants transform sunlight into usable energy – photosynthesis.

One source of error is that two of the plants were inside, and one was outside, which may have had an impact on growth. The method could be improved by requiring all plants to be outside. This would make the investigation valid.

References

BBC, 2019, 'Photosynthesis', BBC Bitesize Articles, accessed 10 January 2024. mea.digital/gsnsw4_9_1.

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.

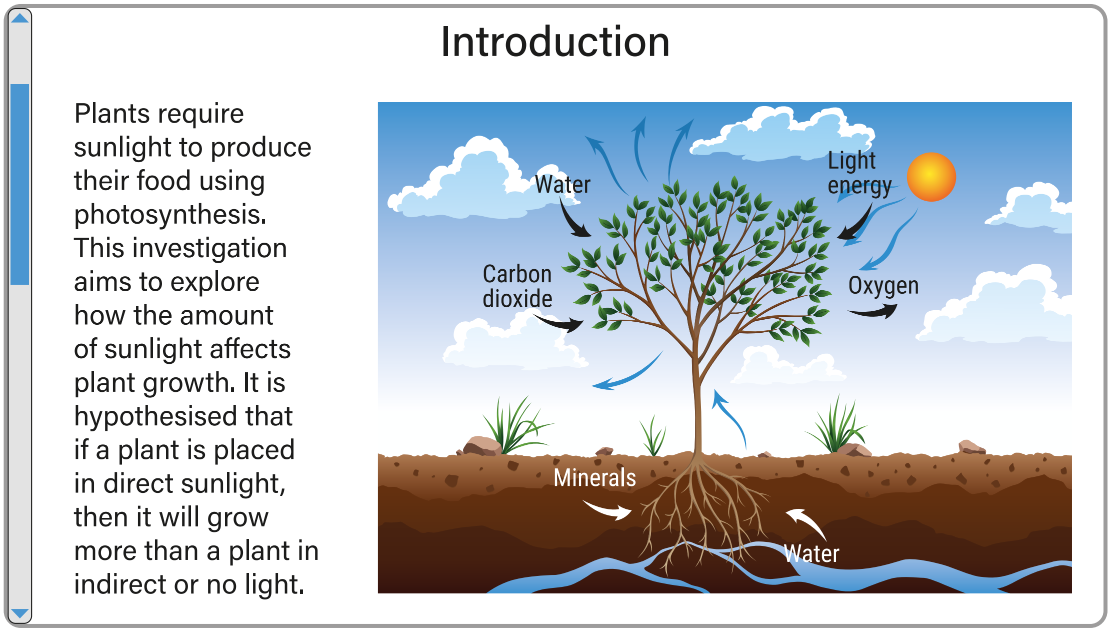


Figure S3.6: An example of a slide layout for a scientific presentation

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 atom. However, it is missing specific labels. To improve the information it communicates and make it a better scientific model, labels should be added. Figure S3.7b is appropriate as it also includes labels of the atom and its structures and components.

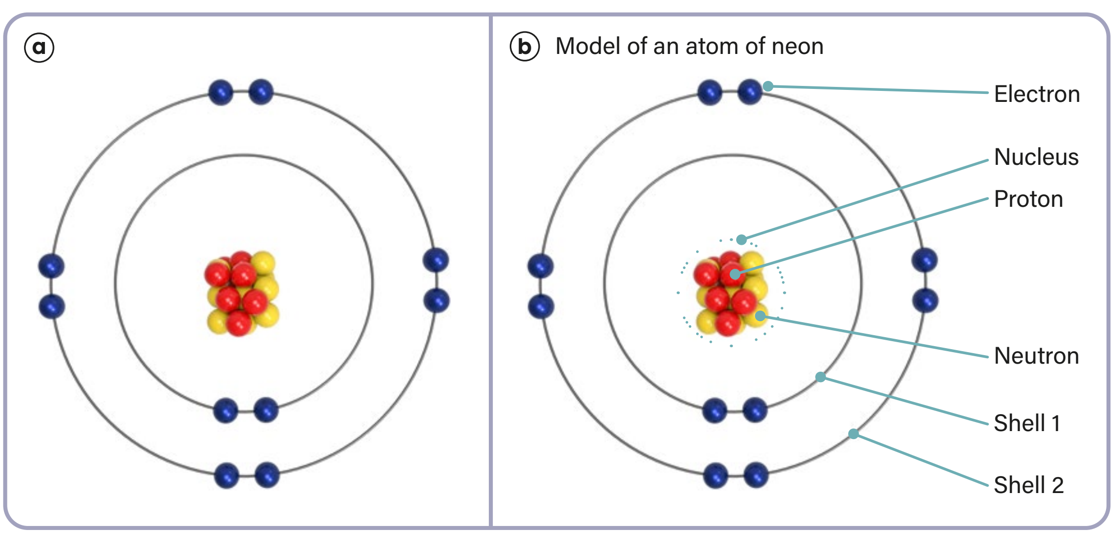


Figure S3.7: (a) A model of an atom of neon that is missing labels; (b) an improved model of an atom of neon including labels

Conducting scientific research

CRAAP

When conducting scientific research, we need to confirm that the information is valid. Even if a source looks credible on the surface, it may not have valid information. One way that we can check this is by using the CRAAP test.

Currency: is the information on the source up to date? Was it recently published (or published in a time relevant to the information)?

Relevance: does the information answer the question I am asking? Is it written in a way that I can understand?

Authority: does the author of the text have experience in this branch of study? Do they have appropriate qualifications to be giving out information on the topic?

Accuracy: where is the information from? Can I find similar information across multiple sources? Is there evidence supporting the information?

Purpose: why is this particular author or company publishing this information? Are they unbiased or are they trying to sell a particular viewpoint? Is the information fact or opinion?

Source: Meriam Library, California State University, Chico.

A secondary source of information must meet *all* of these criteria to be considered a valid source. If the source meets the criteria, use it to support your scientific writing. For example, when looking at the question 'How is water used in Australia?', we can analyse the two sources of information about water set out in Table S3.2. The table shows us that the first source meets all of the CRAAP criteria, making it valid, while the second source only meets two criteria and should be disregarded.

Table S3.2: Evaluating research sources for the topic of water

Source	Source 1: 'Water Use in Australia, 2022–23'	Pass?	Source 2: 'My Opinion on Water Use in New Zealand'	Pass?
Currency	Updated recently, with the date of last update clearly stated e.g. *last updated: 7 June 2023* – current	☑	Updated recently, with the date of last update clearly stated e.g. *last updated: 13 June 2024* – current	☑
Relevance	Provides information on the distribution and use of water in Australia – highly relevant	☑	Provides information on water use, but not in Australia – related, but not relevant for our research question	☑
Authority	Reputable scientific organisations or research bodies that state clearly their qualifications and methods e.g. *Geoscience Australia – a government department focused on water research* – good authority	☑	No listed qualifications, or qualifications are from organisations that don't exist. The author might be an expert in a different field but isn't qualified to be considered an expert on water	☒
Accuracy	Similar information can be found across multiple other reputable sources and is supported by evidence	☑	Very few other sources include similar information; claims are not supported by evidence or are rejected by other experts in the field	☒
Purpose	To educate Australians on where water is and how it is used, using current peer-reviewed scientific research	☑	To share the opinion on water use of one person who is not an expert in the field	☒

Types of information

When conducting research for investigations and articles, it is important to remember to include a variety of primary and secondary sources.

Primary sources are original, or first-hand, material and can include:

- letters or diaries
- photos
- research data
- laboratory notes
- data collected during first-hand investigations.

Secondary sources are materials that evaluate primary sources. These include:

- scientific reports
- journal articles.

There are also *tertiary sources* of information, which include both primary and secondary sources. Tertiary sources include:

- textbooks and encyclopaedias
- general-knowledge websites (make sure the authors are trusted and the information is current).

Some sources of information are considered *non-scientific*. You should not include these in your reports or articles. These include:

- your personal stories – back up your information with evidence!
- blogs or articles that are not based in fact
- personal opinions.

A well-constructed scientific report or article will include a combination of sources. This shows that you have researched widely to ensure that you include valid and trusted information to inform your audience.

Researching information

When researching a scientific topic, sources include:

- textbooks, books, magazines and journals available from a library or online collection
- search engines such as Google; however, do not just use the information that pops up initially – visit the sites listed and ensure they pass the CRAAP test
- specific search sites such as Google Scholar, which will contain scientific journal articles relating to your topic.

When searching for information, remember:

1. Go to sources that contain valid information – check each one against the CRAAP test.
2. Choose three or four key words about your topic and use them when entering search terms into Google or Google Scholar; this should increase the number of relevant sites and articles that appear.
3. Save a copy of the URL (web address) for each website you use, and note down the details or take photos of every textbook or physical source you use. You will need this information when referencing your work at the end of your writing.

Figure S3.8: There are many places to access valid sources of information, 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 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 web page or the name of the publisher of the book
5. for digital content, the date you accessed it and the URL.

For example, below are references for a web article and a journal article.

BBC, 2024, 'Photosynthesis,' BBC Bitesize Articles, accessed 9 February 2025, https://www.bbc.co.uk/bitesize/articles/zn4sv9q.

Hilty J, Muller B, Pantin F and Leuzinger S, 2021, 'Plant Growth: The what, the how and the why,' *New Phytologist*, Volume 232, Issue 1, accessed 9 February 2025, https://nph.onlinelibrary.wiley.com/doi/full/10.1111/nph.17610.

Writing evidence-based essays

As part of your science studies, you will be required to write essays. Your essays must be supported by evidence. This type of scientific writing is usually informative or argumentative. In either case, you will need to structure your essay. One way to do this is to write an essay with five or more paragraphs or sections, consisting of:

- an introduction paragraph
- three or more body paragraphs
- a concluding paragraph.

Each body paragraph should follow the TEEL approach. The TEEL acronym reminds you of what to include in each paragraph of your essay:

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

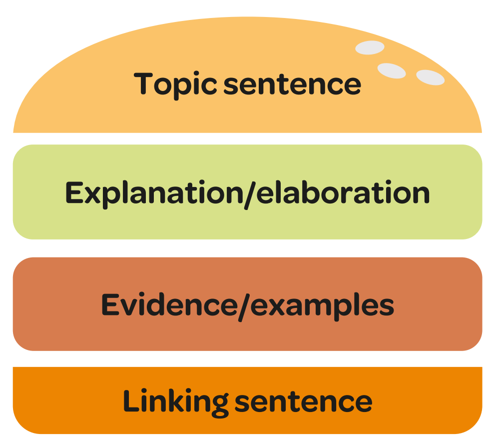


Figure S3.9: Each TEEL paragraph should build on the topic and link to the next idea or the essay as a whole.

Writing an informative essay

Informative scientific essays communicate scientific facts and ideas with a neutral tone, and cover all aspects of a topic. These essays are sometimes called research papers because they summarise multiple sources of research available on a particular topic, without including any opinions or personal narrative. There are many ways to structure an informative essay, such as the TEEL approach.

Writing a scientific argument

A scientific argument presents a position on a particular topic. Instead of all aspects of the research being communicated evenly, the research is evaluated and used by the writer to form a position.

Before you begin writing your argument, you will need to develop an evidence base by conducting research on the topic and evaluating each source. This will help you to choose your position.

For example, if the topic is nuclear power, you should find multiple sources that discuss positive and negative aspects of nuclear energy. Read each research piece carefully and critically. Review and evaluate each source by asking the following questions:

- Is this piece of evidence relevant?
- Is this piece of evidence written by a reputable person or group? (If not, it still may be useful as you could use it to criticise the opposing position.)
- What position does it take?
- Is it valid in taking this position?
- If it is not valid, what are the problems with it?

Use the answers to these questions to decide which position you intend to argue scientifically.

Finally, once you have established your position, you need to write your argument. You can follow the standard essay structure, using five or more paragraphs and the TEEL approach for each paragraph. Usually, each of your body paragraphs should provide a new reason why your position is valid.

S4 Maths in science

Key terms

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

conversion factor: a number used to change one unit of measurement to another

density: how heavy something is for its size; mass divided by volume

equation: a mathematical statement that shows that two things are equal; for example, $2x + 6 = 14$ is an equation that needs to be solved so that $2x + 6$ does actually equal 14

exponent: the superscript value to the right of a number that says how many times to use the number in a multiplication; for example, when we write 10^3, '3' is the exponent. It means we need to multiply 10 by itself 3 times

mathematical formula: a rule or principle that helps you to find the answer to a question or understand the relationship between variables

mean: a measure of centre (an average) calculated by adding all the numbers together and dividing by how many numbers there are

median: the middle number in a set of numbers when they are arranged in order

mode: the number that appears most frequently in a set of numbers

power: the end product obtained by multiplying a quantity by itself one or more times; for example, 2 to the *power* of 3 is $2 \times 2 \times 2$, which is 8, so the *power* of 2^3 is 8

range: in a set of numbers, a measure of spread between the highest number and the lowest number

ratio: a way of comparing like quantities without units

scale factor: the ratio between corresponding measurements of an object and a copy of that object

scientific notation: a way to write very large or very small numbers in a simple form

subscript: a letter or number written slightly below and to one side of another; for example, '2' in H_2O

superscript: a letter or number written slightly above and to one side of another; for example, '2' in 8^2

Understanding and applying basic mathematical concepts is essential for engaging with science effectively. It involves using mathematics to interpret and analyse scientific information, enhancing your comprehension of the scientific ideas you encounter in your studies and daily life.

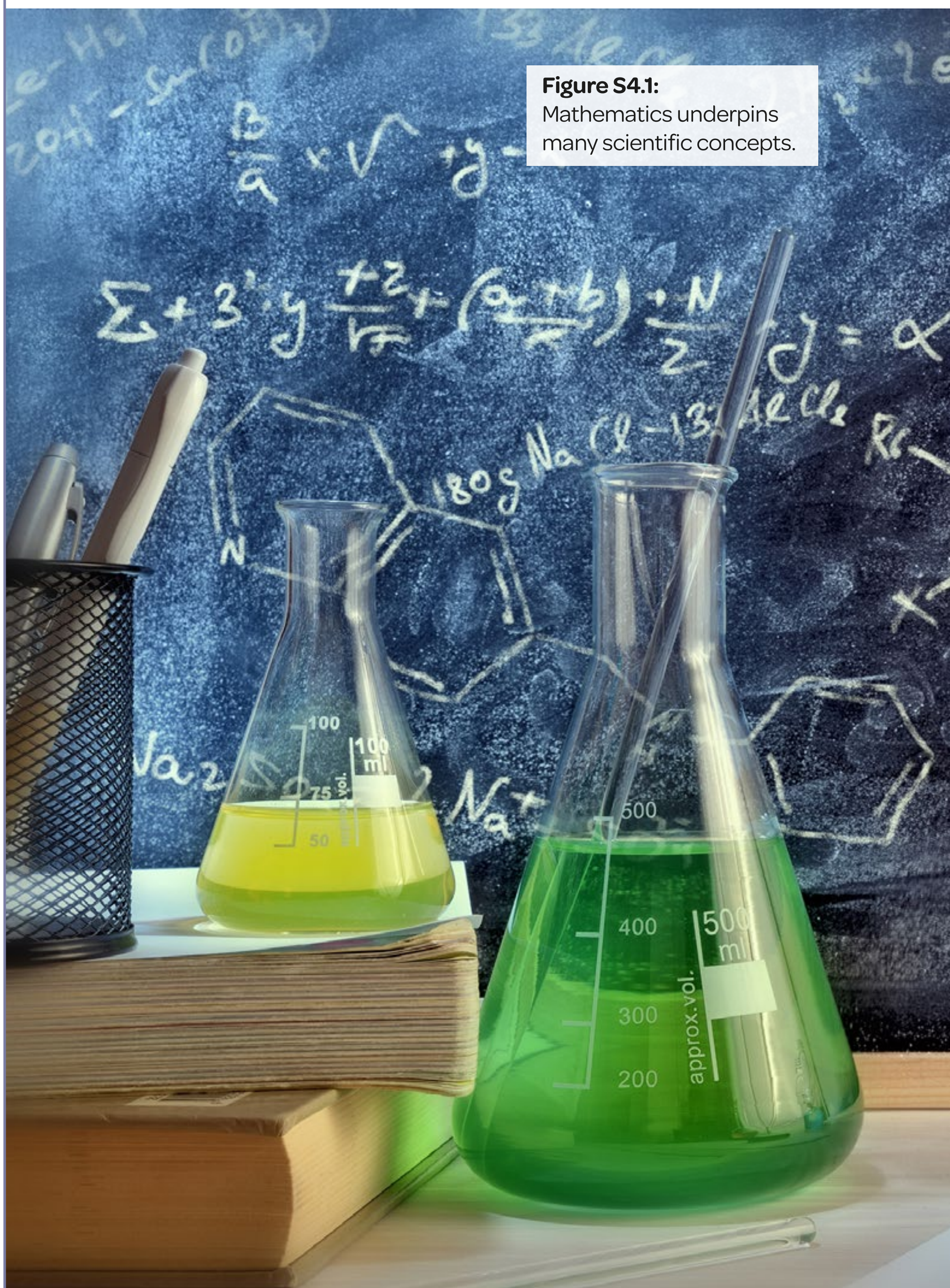


Figure S4.1: Mathematics underpins many scientific concepts.

Units of measurement and converting

When we come across numbers in science, we need to identify:

- what the number is measuring
- the symbol used to represent the measurement
- what unit the number is measured in.

For example, you read that a ball takes 10 seconds to roll down a ramp, and you identify that:

- *time* is the measurement
- the symbol used is *t*
- the unit of measurement used is seconds.

In science, we use an international standard system of units for all types of measurements. These are called 'SI units'. We use some of these units every day, such as using metres to measure distance or minutes to measure time, but some others are only used in advanced science and maths. For example, in this book we use the common unit degrees Celsius (°C) for temperature rather than the SI unit of kelvin (K).

Some numbers do not have units. If you swim two laps of a pool, the length can be measured in metres, but the number of laps will just be '2' with no units because it is a general quantity.

Table S4.1 shows measurements you will come across in this text, their symbol and unit.

Table S4.1: Some common measurements, symbols and units

Measurement	Symbol	Commonly used unit at this level
Length or distance	*D*	metre (m)*
Time	*t*	second (s)*
Speed or velocity	*v*	metres per second (m/s)*
Mass	*m*	gram (g), kilogram (kg)*
Volume	*V*	millilitre (mL)
Concentration	*g*	grams per litre (g/L)
Density	*d*	grams per millilitre (g/mL)
Temperature	*T*	degrees Celsius (°C)
Force	*F*	newton (N)*
Energy	*E*	joule (J)*
Number of ...	*N*	no units

*SI unit

Tip 1: **Capitalisation matters**. Notice that *D* is the symbol for distance, while *d* is the symbol for density. If you mix up the lower and upper cases, it will change the meaning.

Tip 2: **Symbols are not the same as units**. Notice that *m* in *italics* is the symbol for 'mass', while 'm' in regular text is the unit for metres. Symbols are used to represent variables in an equation, while the unit tells us *how* the variable is measured. You should be able to distinguish between symbols and units.

Converting between units

Sometimes you will need to change measurements from one kind of unit to another. You can do this if you know the **conversion factor**. For example, if you are converting minutes into seconds, the conversion factor is 60 seconds (60 s), which is the number of seconds in a minute. At other times, you may need to look up the conversion factor. For example, on Earth a kilogram is about the same as 9.8 newtons, so the conversion factor from 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

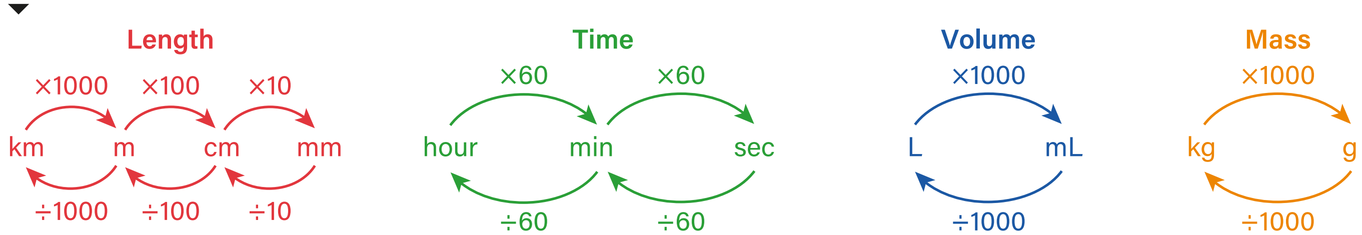
1 (hour) × 60 (minutes) × 60 (seconds) = 3600 **s**

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 2.5 km to metres.
Hint: you are converting to a *smaller unit*; therefore, you need to *multiply*.
The conversion from the chart is to multiply by 1000:
2.5 × 1000 = 2500 m

2 Convert 150 g to kilograms.
Hint: you are converting to a *larger unit*; therefore, you need to *divide*.
The conversion from the chart is to divide by 1000:
150 ÷ 1000 = 0.15 kg

3 Convert: 4 hours to seconds.
The conversion for 1 hour to seconds is to multiply by 60 to get minutes, then multiply by 60 again to get seconds. We also need to multiply by 4 to get 4 hours.
4 × 60 × 60 = 14 400 s

Figure S4.3: The colours of Labrador puppies in a litter can be expressed as ratios.

Understanding ratios

Ratios are a way of comparing like quantities without units. For example, if a pancake recipe asks for one part milk and two parts flour, that is a ratio of 1 to 2. We can write this as 1:2. Ratios do not require units – no matter how much milk you use, you must always use twice as much flour (× 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.

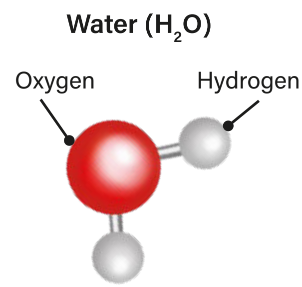


Figure S4.4: This model of water clearly shows the 2:1 ratio of hydrogen to oxygen.

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.

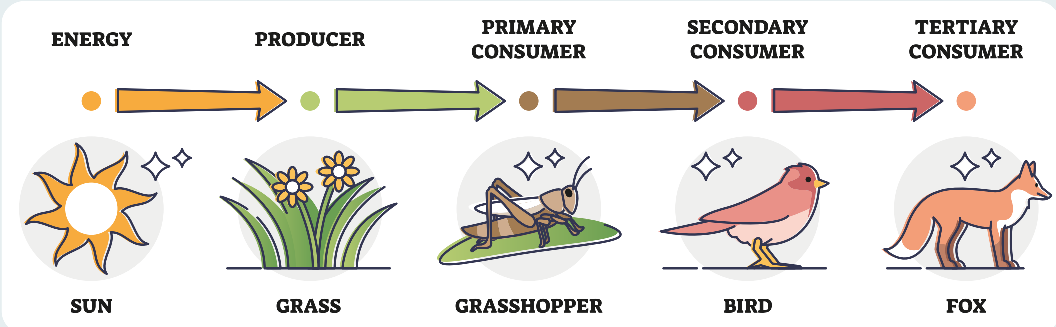


Figure S4.5: Energy moves up a food chain.

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 per cent of the grasshopper's energy store passes up the food chain to the bird.
- This 10 per cent is the *scale factor*.
- Therefore, you multiply 630 by 10.

Calculating averages

Mean, *median*, *mode* and *range* are terms you will often hear when working with data. Mean, median and mode are different ways to measure the centre of the data. Each is used in different situations for different purposes, depending on what you are trying to understand. Range is used to understand the spread of numbers in a dataset. We will go through each of them in turn.

Mean

The **mean** (often called the average) can be used when many measurements are taken of the same thing and you want a value near the centre of all the measurements. This value is often required in scientific investigations when you have conducted multiple trials. The mean is often used in visual representations of the data.

The mean equals the sum of all values divided by the total number of values.

Here is a set of values: 5, 8, 9, 11, 12.

To arrive at the mean or average of the set of values, add them together: 5 + 8 + 9 + 11 +12 = 45. Then divide 45 by the number of values (in this case, 5 values) to calculate the mean.

The mean is 45 ÷ 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 Percentage = $\frac{\text{part}}{\text{whole}} \times 100$

3 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 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 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 term 'per cent' or the percentage symbol (%) must always accompany a percentage value.

This formula can be adapted to suit a variety of situations, as shown in Worked example 7.

Worked example 7: Energy efficiency and percentages

Your hair dryer uses 28 000 joules of energy but only puts out 15 960 joules of blowing energy. What is the percentage efficiency of your hair dryer?

1 Percentage = $\frac{\text{part}}{\text{whole}} \times 100$	Identify the formula for calculating percentage.
2 Efficiency = $\frac{\text{part}}{\text{whole}} \times 100$ Efficiency = $\frac{\text{blowing energy}}{\text{total}} \times 100$	Adapt the formula to suit the problem. We are trying to work out the *efficiency* of the hair dryer.
3 The part = blowing energy = 15 960 J The whole = total energy = 28 000 J	Identify and label the values given in the question.
4 Efficiency = $\frac{15\,960}{28\,000} \times 100$ 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 term 'per cent' or the percentage symbol (%) must always accompany a percentage value.

There is a lot more to learn about percentages and how they are used in science, including how to calculate percentage error. You will learn more about this in later years.

Scientific notation

Scientific notation, sometimes called standard form, helps us to write very large or very small numbers in a simpler way. Every number can be written in scientific notation as the product (product = multiply, or times) of two numbers that are:

- a decimal greater than or equal to 1 and less than 10
- a **power** of 10 written as an **exponent**. (An example of an exponent is 10^3, which is the same as 10 × 10 × 10. The '3' (a **superscript**) means that the 10 is multiplied by itself 3 times.)

2.56×10^3 is an example of scientific notation. It is a different way of writing the number 2560. It is the same as writing 2.56 × 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 8 and 9, we will explore writing large and small numbers in scientific notation.

Worked example 8: Scientific notation for large numbers

1 Write 65 000 000 in scientific notation.

- 65 million is a very large number.

2 Turn 65 000 000 into a decimal > 1 and < 10.

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.

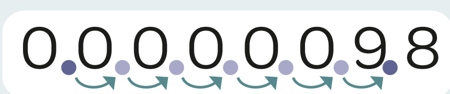
- The number of times you move the decimal point to the left becomes the power you need to write your number as in scientific notation. You moved the decimal point 7 times, so the power is 10^7. It is a positive power.
- Remember: when you are expressing a very large number in scientific notation, move the decimal point *left* to create your decimal. Your power will be *positive*.

Worked example 9: Scientific notation for small numbers

1 Write 0.000 009 8 in scientific notation.

- 0.000 009 8 is a very small number less than 1.

2 Turn 0.000 009 8 into a decimal ≥ 1 and < 10. It becomes:



It becomes 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.

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 3237	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% in 2018, 24% in 2019, 32% in 2020, 45% in 2021 and 60% in 2022. This data could be displayed in a line graph.

Remember that the independent variable (changed factor) should go on the horizontal axis, the *x*-axis. In this case, that would be the year the car was sold. The dependent variable (measured factor) should go on the vertical axis, the *y*-axis. This would be the percentage of cars with airbags. Each axis should have a label and an even scale.

Plotting points

Once you have drawn an even scale, you can plot the points on the graph:

1. Locate the relevant data on the *x*-axis (e.g. year 2018).
2. Locate the relevant data on the *y*-axis (e.g. percentage 18%).
3. Trace on the graph to where the two points meet.
4. Where the points intersect, plot the point by drawing an 'x' on the spot.
5. Continue plotting points for each piece of data.

Line of best fit

Once all of the data points are on your graph, you can add a trend line, known as the 'line of best fit'. This line will go through the middle of most of the points, but will not necessarily connect the dots between each. A line of best fit can be straight (ruled) or curved, depending on the data. Use the following instructions to draw a line of best fit:

1. Look at all the points on the graph. Do they make a straight or curved line?
2. For a straight line, place a ruler on the graph, through the points. Move it until most of the points are close to or touching the line. Carefully rule the line on the graph, continuing past the final point to the end of the *x*-axis.
3. For a curved line, carefully sketch a single line curve through the data points, and continue it to the very top of the graph, or the edge of the *x*-axis.

Your finished graph should look similar to Figure S4.8.

Figure S4.8 shows a scatter plot for the data given in the example. From this graph, we can see a *trend*. A trend describes what the data is showing. In this case, cars sold with airbags are increasing as the years increase. This is a positive trend.

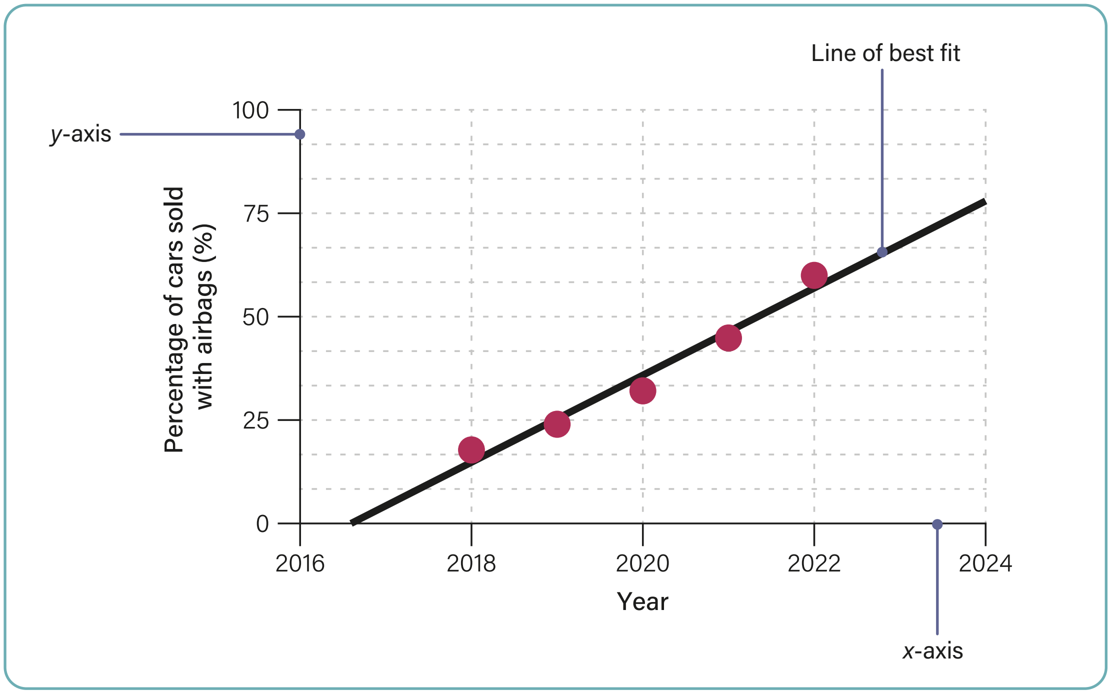


Figure S4.8: Percentage of cars sold with airbags (%) per year, 2016–2024

Column graphs

Column graphs are used to compare separate categories of the same type of data. This means that there is a distinction between the independent variables – each is its own separate category. However, they are still measured against the same criterion.

For example, in City X the average daily maximum temperature for the month was recorded for every month of a year (2024). The results were 33 °C in January, 30 °C in February, 25 °C in March, 19 °C in April, 17 °C in May, 12 °C in June, 8 °C in July, 10 °C in August, 13 °C in September, 20 °C in October, 27 °C in November and 31 °C in December. This data could be displayed in a column graph.

Remember that the independent variable (changed factor) should go on the horizontal *x*-axis. In this case, it is the month of the year. The dependent variable (measured factor) should go on the vertical *y*-axis. This is the temperature in degrees Celsius (°C). Each axis should have a label and an even scale.

Adding columns

Once you have drawn an even scale, add the columns to the graph:

1. Locate the relevant data on the *x*-axis, such as the month of January.
2. Locate the relevant data on the *y*-axis, such as the temperature of 33 °C.
3. Trace on the graph to where the two points meet.
4. Where the points intersect, put a small pencil mark.
5. Using a ruler, extend the point out on each side of the mark, and then down to the *x*-axis to make a column.
6. Continue for each piece of data on the *x*- and *y*-axes.

A completed column graph from the data above should look similar to Figure S4.9.

Note: If you prefer, the data represented as a column graph here could also be represented as a line graph.

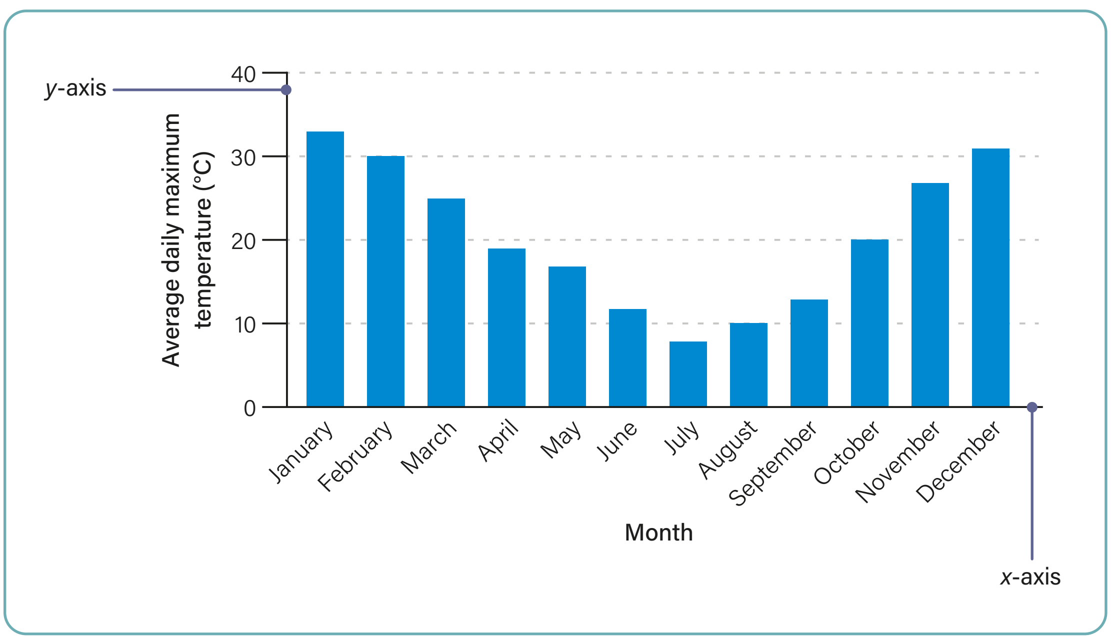


Figure S4.9: Average daily maximum temperature across months of the year in City X, 2024

Making pie charts

A pie chart is a visual representation of parts of a whole. The 'pie' is a circle where each 'piece' represents a fraction or percentage. Therefore, the whole circle represents the whole thing: 100 per cent.

To make a pie chart, the size of each 'piece' should reflect the percentage it represents. So, if one of the parts is 25 per cent, that piece should take up a quarter of the pie, which is 25 per cent.

When there are lots of parts, It can be difficult to estimate the size of each piece by hand. Ideally, you should use a computer program like Microsoft Excel, or an app for making pie charts, to ensure your pieces are the right size for each part they represent, but if you are creating your pie chart by hand, you can estimate. A helpful way to approach this is to divide your circle into eight equal pieces. Each piece is 12.5 per cent of the circle, which will help you to make your estimates.

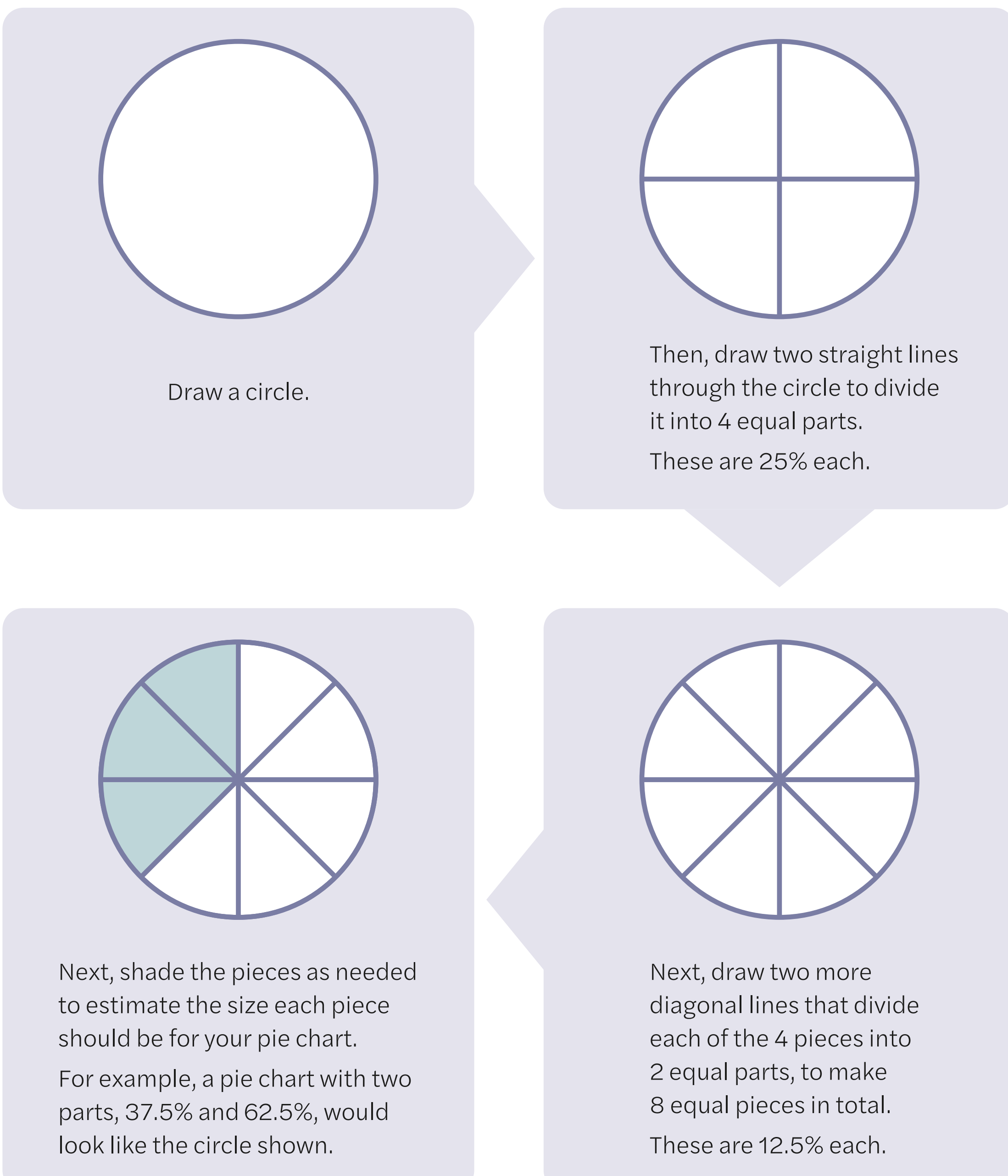
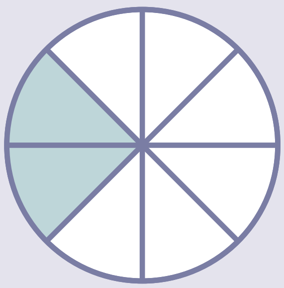
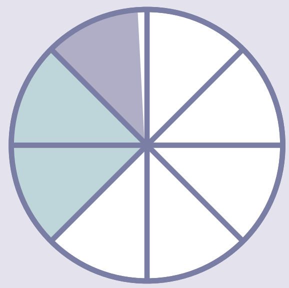


Figure S4.10: How to create a simple pie chart using estimates

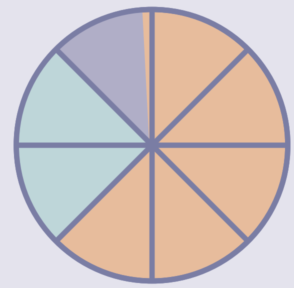
Let us say the percentages you want to represent in a pie chart are 25%, 12% and 63%.



- Start with the pie divided into 8 pieces.
- If any of the parts are exactly 12.5% or multiples of 12.5%, shade those first.
- 25% is 12.5 × 2, so this is a good part to shade first in your pie chart, using 2 pieces to represent 25%.



- The next value to represent in your pie chart is 12%.
- Since each piece is 12.5%, you will estimate the part to be slightly smaller than one piece of the pie.
- Shade this in a different colour to the 25% part.



- The remaining part should be 63% of the circle. This is about 5 pieces (5 × 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.

▲ **Figure S4.11:** Representing three amounts in a pie chart using estimates

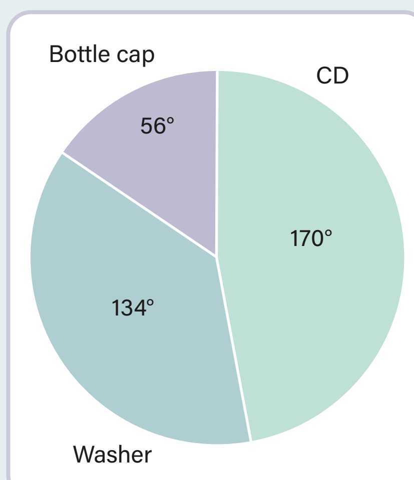
This is one way to estimate the size of the pieces of a pie chart when drawing by hand. Explore other ways to draw pie charts by hand, such as by using a tape measure, a protractor, or a circle with 10 equal pieces that are 10 per cent each. However, when you need to formally present your information, it is best to create the pie chart digitally, to make the pieces of your pie chart as exact as possible.

Worked example 10: Drawing pie charts

To create each sector, first add up the total distance. In our investigation results, Table S2.5 on page 231, 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 ÷ 70 × 360 = 56 degrees
CD	33	33 ÷ 70 × 360 = 170 degrees
Washer	26	26 ÷ 70 × 360 = 134 degrees



▲ **Figure S4.12:** The finished chart clearly shows each part of the whole distance.

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.

Using formulas to determine an unknown value

Mathematical formulas are used to show the mathematical relationship between variables. Often, you will be given all the values of variables in a particular **equation** except for one (the unknown). You can use the formula to solve the equation to find the unknown. However, before you apply a formula, you need to determine which formula will be best to use.

Follow these steps to identify and use scientific formulas to determine an unknown value:

1. Read the question carefully. Identify and label the values that are given in the question, and the variable you are trying to determine.
2. Consider the variables you have listed. Identify the formula that includes those variables.
3. Rearrange the formula, as needed, based on your unknown variable, and substitute in known values.
4. Solve for the unknown, keeping the same units as indicated by the given values, or convert units if required by the question.

To practise these steps, we will look more closely at a specific formula.

Density is a measure of how heavy something is compared to how much space it takes up. This relationship can be shown mathematically:

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

When we replace the words with their symbols (in *italics*), it is now a formula equation:

$$d = \frac{m}{V}$$

Worked example 11 will help you to understand how to use this formula to determine an unknown value

Worked example 11: Choosing a formula to determine an unknown value

You pour a cup of tea and measure a volume of 30 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, d = ?

- Collect the information you have been given: You know the volume of honey and the mass of the tea. You do not know the density of the honey. That is what you are trying to work out.

2 $d = \frac{m}{V}$

- Choose the formula that allows you to use the information you have collected. The formula is for density.

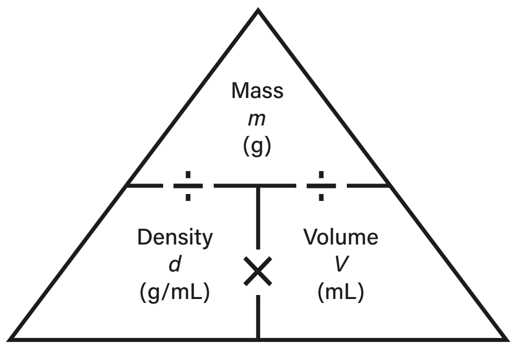
3 $d = \frac{42}{30}$

- Calculate the density of the honey by substituting the known values into the formula. (You can use your calculator.)

4 Answer: $d = 1.4$ **g/mL**

- $42 \div 30 = 1.4$
- Remember to use the same units as the given values in your answer.

The density formula can be rearranged to determine mass or volume, if you know the other two variables. For example, if you are solving for mass, the formula is rearranged to $m = d \times V$. If you know the mass and density, the formula to solve for volume is $V = m/d$.



S5 Using scientific equipment

Good science involves curiosity, a desire to understand the world, and a passion for improvement and innovation. Good science also means conducting investigations safely and accurately, which includes knowing your equipment and how to use it. In this section, we will familiarise ourselves with common equipment.

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.

Figure S5.1: Working with chemicals requires following safety information and wearing personal protective equipment (PPE).

Protective equipment: Wear safety glasses, gloves and a laboratory coat to protect you from any chemical splashes or spills.

Instructions: Listen to and read all instructions carefully before you start your investigation.

Equipment: Inspect all equipment to make sure you have the correct items for your specific investigation. Ensure equipment is intact and working properly.

Consumption: Food and drink can become contaminated. Never bring or consume food or drink in the laboratory.

Energy: Manage your energy levels so that you are walking sensibly and holding equipment securely while moving around the lab.

For more information on safety in science, see Section 1.6 of Chapter 1 on page 16.

Pictograms

Pictograms are a part of science safety. They are used to label chemicals with their known hazards. Figure S5.2 shows some pictograms you are likely to see in the laboratory.

Pictograms are used across many industries, so you may recognise them from cleaning products used in your home. Pay close attention to the pictograms on the chemicals you use in the laboratory and follow any warnings. Some chemicals may not be hazardous, so you will not see any pictograms. Others may have several hazards and contain several pictograms for a single substance.

There are many more pictograms than the ones shown here, so be sure to ask your teacher if you come across an unknown pictogram.

Figure S5.2: ▶ Common warning pictograms

Flammables

Gases under pressure

Acutely toxic

Burns skin, damages eyes, corrosive to metals

Explosives

Oxidisers

Toxic to aquatic environment

Health hazard

(Chronic health hazards, denoted by the health hazard pictogram, include carcinogens, reproductive toxins, mutagens, specific target organ toxicants, and aspiration toxicants.)

Acutely toxic (harmful)

(Other health hazards, denoted by the exclamation mark pictogram, include skin, eye and respiratory irritation, allergic skin reactions, drowsiness and dizziness.)

▲ **Figure S5.3:** Pictograms show the chemicals in your laboratory that are hazardous.

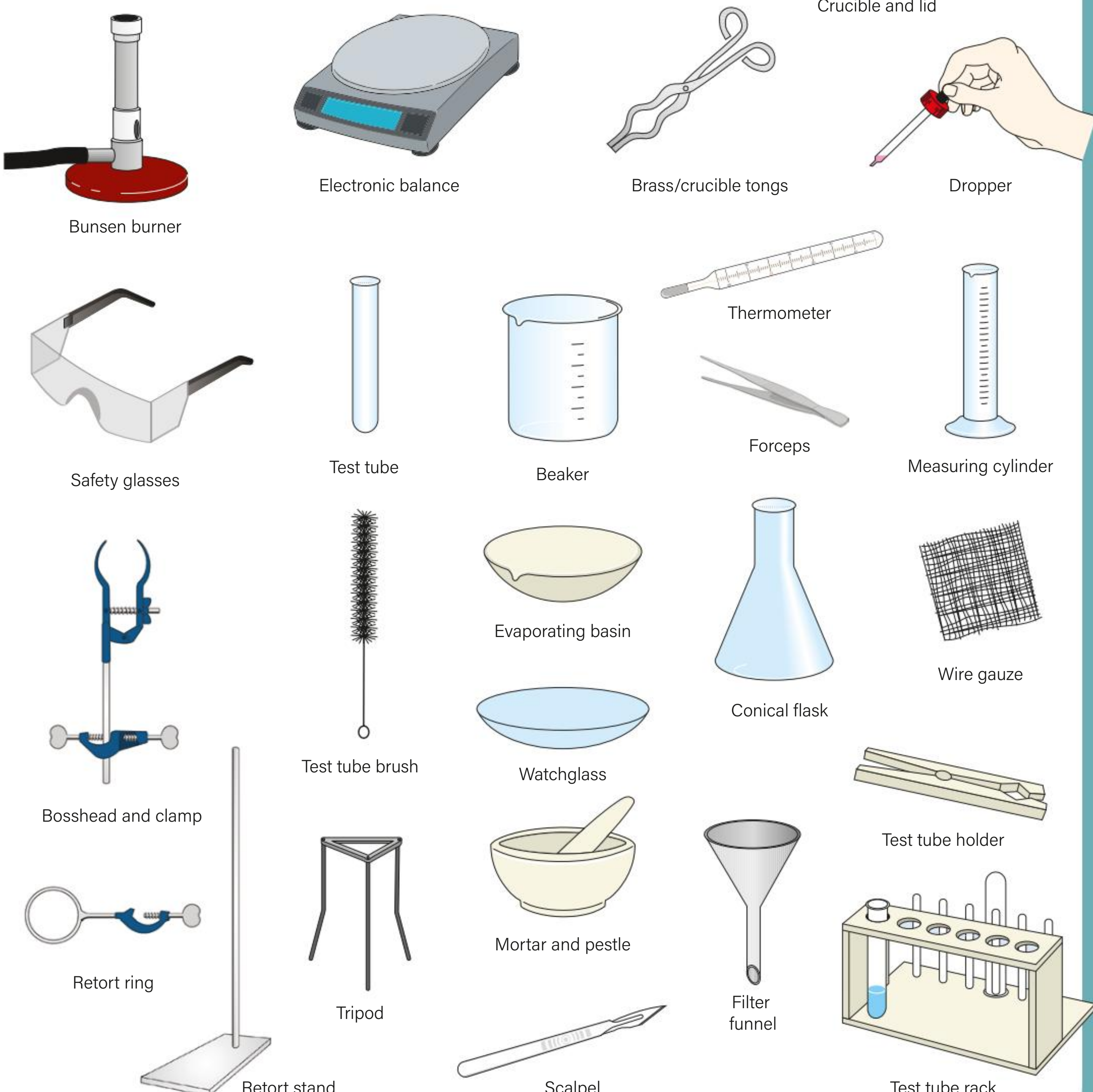
Laboratory equipment

Get to know common laboratory equipment

By learning the names and uses of laboratory equipment, you can select and use the correct equipment for any investigation. Some of the most common equipment is shown here.

Note: you should already be familiar with Bunsen burner use and safety. For a refresher, see Section 1.6 on page 16.

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.

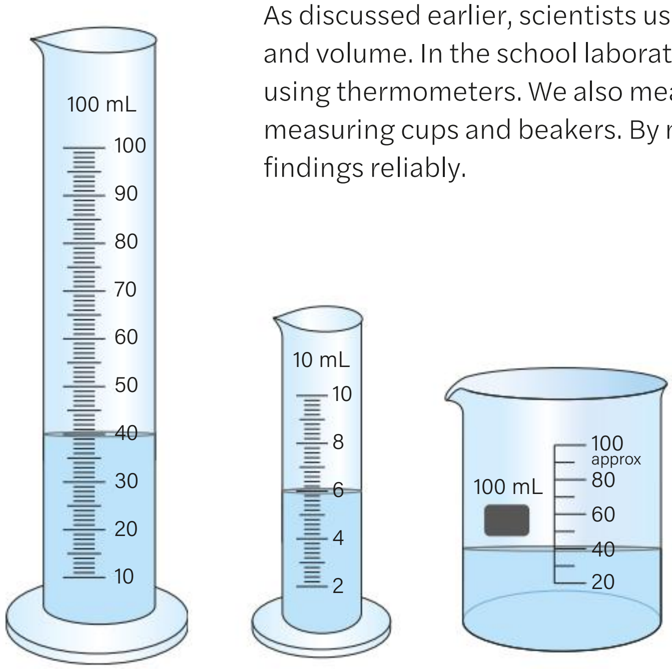


Figure S5.5: Beakers and measuring cylinders

Volume measurements

Reading volume measurements is not as easy as it might seem. It requires an understanding of how liquids can curve and the ability to take this into account. You need to use specific equipment, which will help you to measure accurately.

Equipment for measuring volume

Beakers and measuring cylinders are the most common pieces of equipment you will use to measure volume. As they are filled with liquid, the measurement reading increases.

When precision matters, always use the smallest measuring cylinder available that can measure the required amount. For example, if you need to measure 8.0 mL of something, it is best to use a 10 mL measuring cylinder to get the most accurate result.

Observing the meniscus

Because of **surface tension**, liquids do not form a flat surface in a relatively small container. Instead, a curve forms, which is called the **meniscus**. You should take volume readings at eye level, at the very bottom of a **concave** meniscus, as shown in Figure S5.6. It is obvious that the bottom of the meniscus is between the 36 mL and 37 mL increment lines, which is recorded with certainty. The place value after the increment marks – in this case, the tenth place (.0) – should be estimated. Therefore, the measurement for this volume is 36.5 mL, where the .5 is uncertain.

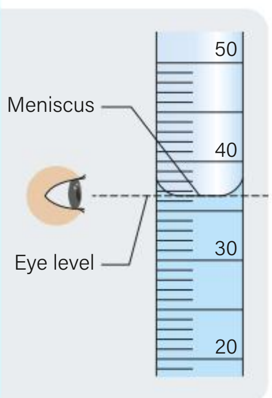


Figure S5.6: Take volume readings at eye level.

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.

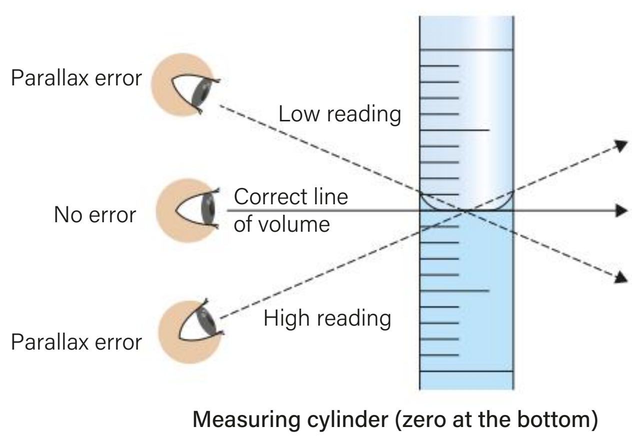


Figure S5.7: To avoid parallax error bring yourself down to the appropriate level. This takes practice.

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.

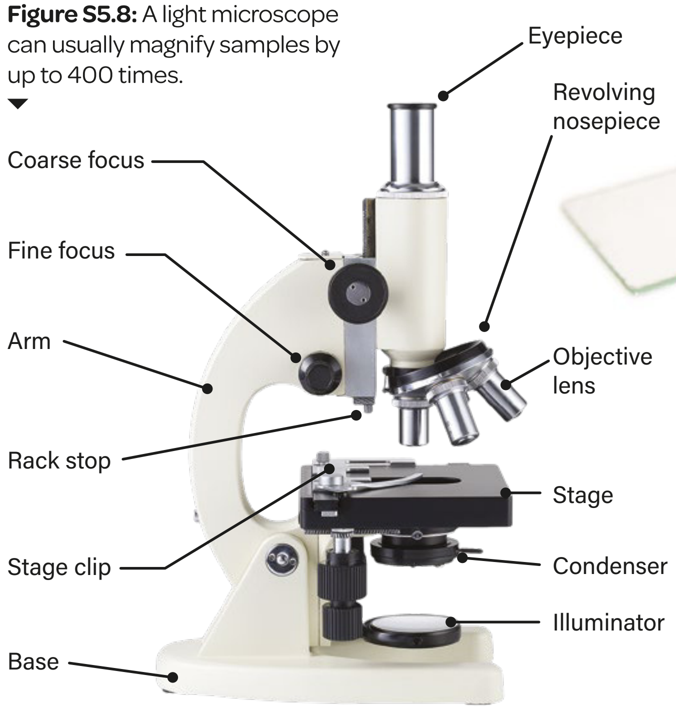


Figure S5.9: Microscope slides are usually made of glass and are very fragile – treat them carefully.

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 the actual size.
6. Carefully insert the microscope slide onto the top of the stage and hold it firmly under the stage clip. Position it so the object you need to see is in the middle of the stage.
7. Look through the eyepiece and slowly bring the stage upwards towards you, using the coarse focus knob. This can take some time and everything will look bright and fuzzy until you get a glimpse of the slide as it comes into focus.
8. When the slide is roughly in focus, use the fine focus to turn it into a clear image.
9. Increase the magnification by changing the objective lens to 10×, 20× or 40×.
10. 40× is usually the highest available magnification and can be tricky to find and focus on. It can also bring the lens extremely close to the slide, enough to crack and break it – monitor this carefully.

Investigations

Investigation number	Investigation title	Inquiry skill	Inquiry skill focus	Teacher demon-stration
Chapter 1 Introduction to science		**Questioning and predicting, Planning and conducting, Communicating**		
1.6	Using a Bunsen burner	Planning and conducting	Describing ways to minimise risk	
1.8	Comparing observations	Communicating	Preparing representations to communicate findings	
1.9	Using scientific equipment to make observations	Questioning and predicting	Developing a hypothesis	
Chapter 2 Classification		**Questioning and predicting, Planning and conducting, Communicating**		
2.2	Classifying items	Planning and conducting	Generating and recording data	
2.4	Classifying supermarket items	Planning and conducting	Distinguishing between variables	
2.5	Investigating features of marine animals	Communicating	Preparing representations to communicate findings	
2.7	Investigating structural adaptations	Questioning and predicting	Making predictions	
Chapter 3 Ecosystems		**Processing, modelling and analysing, Evaluating, Communicating**		
3.1	Identifying community members in a terrestrial ecosystem	Communicating	Presenting scientific findings	
3.3	Measuring abiotic factors	Evaluating	Identifying investigation errors and assumptions	
3.5	Algal balls	Processing, modelling and analysing	Identifying and discussing trends in data	

Investigation number	Investigation title	Inquiry skill	Inquiry skill focus	Teacher demonstration
Chapter 4 Theories of matter		**Questioning and predicting, Planning and conducting, Processing, modelling and analysing**		
4.1	Compressing liquids and gases	Planning and conducting	Distinguishing between variables	
4.2	Heating materials	Processing, modelling and analysing	Organising data	
4.3	Expanding gases	Processing, modelling and analysing	Identifying data	
4.4A	Changing states of water	Questioning and predicting	Constructing scientific questions	
4.4B	Exploring melting points	Questioning and predicting	Making predictions	
4.5	Exploring density	Planning and conducting	Generating and recording data	
4.6A	Water as a solvent	Questioning and predicting	Making predictions	
4.6B	Solubility and temperature	Questioning and predicting	Developing a hypothesis	
Chapter 5 Mixtures		**Planning and conducting, Processing, modelling and analysing, Evaluating**		
5.1	The Tyndall effect	Planning and conducting	Generating and recording data	
5.2	Solutes and solvents	Processing, modelling and analysing	Identifying data	
5.3A	Calculating the concentrations of solutions	Evaluating	Identifying investigation errors and assumptions	
5.3B	Preparing dilutions	Evaluating	Describing types of errors	
5.4	Purifying muddy water	Planning and conducting	Identifying scientific equipment	
5.5A	Evaporating a solution	Processing, modelling and analysing	Organising data	
5.5B	Growing crystals	Processing, modelling and analysing	Processing data	
5.5C	Demonstrating distillation	Processing, modelling and analysing	Constructing graphs	✓
5.6	Separating colours in dyes by paper chromatography	Planning and conducting	Generating and recording data	
5.9	Purifying oily water	Evaluating	Describing types of errors	✓
5.10	Calculating density	Processing, modelling and analysing	Processing data	

Investigation number	Investigation title	Inquiry skill	Inquiry skill focus	Teacher demon-stration
Chapter 6 Earth's resources		**Planning and conducting, Evaluating, Communicating**		
6.1	Investigating classroom resources	Communicating	Selecting communication formats	
6.2	Making bioplastic	Planning and conducting	Describing ways to minimise risk	
6.3	Investigating soil erosion	Evaluating	Supporting findings with evidence	
6.4	Designing a windmill to lift a weight	Communicating	Using digital technologies to organise and present findings	
6.5	Mining for chocolate chips	Evaluating	Describing types of errors	
Chapter 7 Earth, the Sun and the Moon		**Questioning and predicting, Processing, modelling and analysing, Evaluating**		
7.1	Modelling day and night	Questioning and predicting	Developing a hypothesis	
7.3	Modelling the seasons	Processing, modelling and analysing	Constructing graphs	
7.4	Modelling eclipses	Evaluating	Supporting findings with evidence	
7.5	Modelling the Moon's phases	Questioning and predicting	Constructing scientific questions	
7.8	Making a simple telescope	Processing, modelling and analysing	Analysing scientific models	
7.9	Creating a scale model of the solar system	Evaluating	Identifying investigation errors and assumptions	
Chapter 8 Forces and simple machines		**Questioning and predicting, Processing, modelling and analysing, Evaluating**		
8.1	Push, pull or twist	Processing, modelling and analysing	Organising data	
8.2	Balloon rockets	Questioning and predicting	Making predictions	
8.3	Blowball	Processing, modelling and analysing	Identifying and discussing trends in data	
8.4	Heat from friction	Evaluating	Identifying investigation errors and assumptions	
8.5	Friction of materials	Questioning and predicting	Developing a hypothesis	
8.6	Measuring gravity	Processing, modelling and analysing	Constructing graphs	
8.7	Crash cushions	Processing, modelling and analysing	Analysing processed data	
8.8A	Making a catapult	Evaluating	Identifying investigation errors and assumptions	
8.8B	Using ramps	Evaluating	Constructing evidence-based arguments	
8.8C	Modelling a seesaw	Evaluating	Describing types of errors	
8.8D	Pulley investigation	Evaluating	Supporting findings with evidence	

Investigation 1.6

45 min

Using a Bunsen burner

Inquiry skill: Planning and conducting

Inquiry skill focus: Describing ways to minimise risk

When working with scientific equipment like a Bunsen burner, it is important to identify and describe ways to minimise the risks before commencing your investigation. Complete Question 1 before you start your investigation.

Hint 1: *What risks are associated with using a Bunsen burner, and how can we prevent these from occurring?*

Hint 2: *If you need help with structuring your risk assessment, see the Science how-to section on page 229.*

Aim

To investigate how long it takes to heat different volumes of water to 50 °C using a Bunsen burner

Materials

For each group:

- safety glasses
- heatproof gloves
- laboratory coat
- heatproof mat
- Bunsen burner
- tripod
- gauze mat
- retort stand
- bosshead and clamp
- 200 mL measuring cylinder
- 500 mL tap water
- 250 mL beaker
- matches
- gas tap
- stopwatch

Method

1. Copy the risk assessment table (Table INV1.6a in Question 1) into your notebook and fill it in.
2. Copy the results table into your notebook, adding a title.
3. Set up the equipment as shown in Figure INV1.6. Put on the safety glasses.
4. Using the measuring cylinder, measure 50 mL of cold tap water and pour it into the beaker. Place the beaker on the gauze mat above the Bunsen burner.
5. Place the thermometer into the beaker, so that it is in the water but not touching the glass at the base of the beaker. Hold it in place using the clamp.
6. Make sure the collar of the Bunsen burner is closed.
7. Light a match and hold it over the top of the Bunsen burner, while your partner slowly turns on the gas. (The flame will be yellow and wavy, as the collar is closed.)
8. Start the stopwatch when the Bunsen burner is lit.
9. Turn the collar to expose the air holes, to make the flame blue.
10. Observe the water and the thermometer. When the water reaches 50 °C, stop the stopwatch.
11. Record in the results table the time it took the water to reach 50 °C.
12. Repeat steps 4–11, using 100 mL, 150 mL and 200 mL of cold tap water.

continues ▶

Questions

1 Complete a risk assessment for your investigation, using the following table. Add more rows as necessary.

Table INV1.6a: Risk assessment

Hazard	Risk	Minimisation strategy
Flame	High risk of burns to skin	Keep fingers and hands away from the flame to prevent it contacting the skin.

2 Identify the volume of water that heated up the quickest.

3 Describe a way that you ensured your investigation was safe.

4 Explain why you think you got the results you did from this investigation.

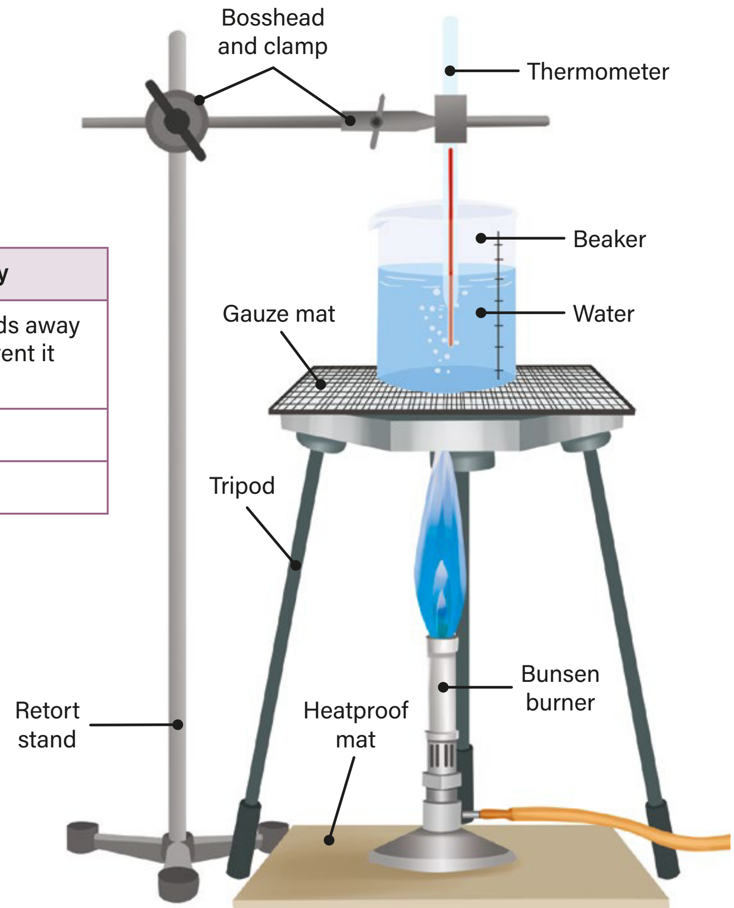


Figure INV1.6: This is how your investigation should look when you have set up your Bunsen burner.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table INV1.6b: Results

Volume of water (mL)	Time to heat to 50 °C (minutes)

⚠

ALWAYS HAVE THE BUNSEN BURNER ON THE YELLOW SAFETY FLAME WHEN NOT IN USE. AN OPEN FLAME, MATCHES AND BOILING WATER ARE HAZARDOUS AS THEY CAN CAUSE BURNS IF THEY TOUCH THE SKIN OR EYES.

WEAR A LABORATORY COAT AND SAFETY GLASSES AND KEEP HANDS AND HAIR AWAY FROM FLAMES. LONG HAIR MUST BE TIED BACK.

NEVER RUN WHILE CARRYING GLASSWARE. CARRY IT WITH TWO HANDS. PLACE GLASSWARE AWAY FROM THE EDGE OF THE LABORATORY BENCH. TAKE CARE WITH HOT GLASSWARE. ALLOW THE BEAKER AND THE HOTPLATE TO COOL SLIGHTLY BEFORE ADDING MORE COLD WATER, TO AVOID THE POSSIBILITY THAT THE BEAKER WILL SHATTER FROM THE COLD WATER OR FROM THE MUCH HOTTER HOTPLATE AFTER COLD WATER HAS COOLED THE BEAKER. THE TRIPOD AND GAUZE MAT WILL BECOME HOT. DO NOT TOUCH, AND LEAVE EQUIPMENT TO COOL BEFORE PACKING IT AWAY.

IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND RUN COOL TAP WATER OVER THE BURN FOR 20 MINUTES.

Investigation 1.8

45 min

Comparing observations

Inquiry skill: Communicating

Inquiry skill focus: Preparing representations to communicate findings

When making observations, it is important to communicate the investigation findings appropriately. This means being able to prepare an appropriate representation that demonstrates what we have observed and inferred.

Hint 1: *What scientific terminology can you use to describe the features of your leaf?*

Hint 2: *What sort of format would allow you to best represent your findings?*

Aim

To make and compare observations of leaves using your senses and scientific equipment

Materials

For each group:

- plant leaves (collected from the school yard)
- magnifying lens
- microscope

Method

1. Copy the results table into your notebook, adding a title.
2. Collect two different types of leaves from the school yard.
3. a. Inspect the leaves using your senses. What observations can you make about them?
   b. Record your observations in the results table.
4. a. Inspect the leaves using the magnifying lens. Have your observations changed?
   b. Record any new observations in the results table.
5. a. Place the leaves under a microscope. Observe the leaves at high magnification. Can you make any new observations?
   b. Record any new observations in the results table.

Questions

1. Which senses did you use to make observations of your leaves?
2. How did using the magnifying lens change your observations?
3. Describe some of the key features you observed about each leaf.
4. What inferences can you make about the leaves based on your observations?
5. Construct an appropriate visual representation to communicate your findings about your selected leaves. Make sure your representation includes both visual and written components.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Figure INV1.81.8: Try to find leaves from native plants, like these leaves from a eucalyptus tree.

Table INV1.8: Results

Plant leaf	Observations using your senses	Observations using a magnifying lens	Observations using a microscope

Investigation 1.9

Using scientific equipment to make observations

Inquiry skill: Questioning and predicting

Inquiry skill focus: Developing a hypothesis

A key component of first-hand investigations is making a prediction of the expected outcome of the investigation. This is done by constructing a scientific hypothesis, which states what we are expecting to happen. A hypothesis directly relates the independent (changed) and dependent (measured) variables. For more on these, see the Science how-to section on page 224.

Hint 1: Using the format 'If ... then ...' will help you to structure your prediction correctly.

Hint 2: Remember that we are stating the expected outcome. At what temperature would you expect the water to boil, based on your own prior knowledge?

⚠

AN OPEN FLAME AND BOILING WATER ARE HAZARDS. BE CAREFUL. ENSURE YOUR HAIR IS TIED BACK, INCLUDING A LONG FRINGE. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES.

Aim

To investigate the temperature at which water boils

Materials

For each group:

- safety glasses
- heatproof gloves
- heatproof mat
- Bunsen burner
- tripod
- gauze mat
- retort stand
- bosshead and clamp
- 100 mL measuring cylinder
- tap water
- 250 mL beaker
- thermometer
- matches
- stopwatch

Method

1. Complete Questions 1 and 2 (see next page) to construct a prediction of your expected outcome of the investigation in your notebook.
2. Copy the results table into your notebook, adding a title.
3. Set up equipment as shown in Figure INV1.9 on the next page. Put on the safety glasses.
4. Using the measuring cylinder, measure 50 mL of cold tap water. Pour the water into the beaker. Place the beaker on the gauze mat above the Bunsen burner.
5. Record the initial temperature of the water using the thermometer. Record this temperature in the results table.
6. Use the matches to light the Bunsen burner. Turn to the blue flame. Start the stopwatch.
7. Observe the water. When the water starts to boil (bubble rapidly), turn off the Bunsen burner. Stop the stopwatch.
8. a Record the temperature of the boiling water in the results table.

   b Record the time it took for the water to boil in the results table.

Table INV1.9: Results

Trial number	Cold water temperature (°C)	Boiling water temperature (°C)	Time taken to reach final temperature (minutes)

45 min

9 Repeat the experiment twice to see if the results are consistent.

10 Wearing heatproof gloves, hold the beaker with both hands and pour the water into the sink.

Questions

1 Identify the independent (changed) and dependent (measured) variables of this investigation.

2 Develop a hypothesis for this investigation using the following sentence: 'If the water ..., then it will boil at ...'

3 Identify the piece of equipment that allowed you to quantitatively measure your observations of the water.

4 Explain how you precisely recorded this quantitative data. *Hint:* How many decimal places did you record?

5 Propose a conclusion that you drew from the data you collected.

6 Did the data you collected support your hypothesis? Explain why or why not.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

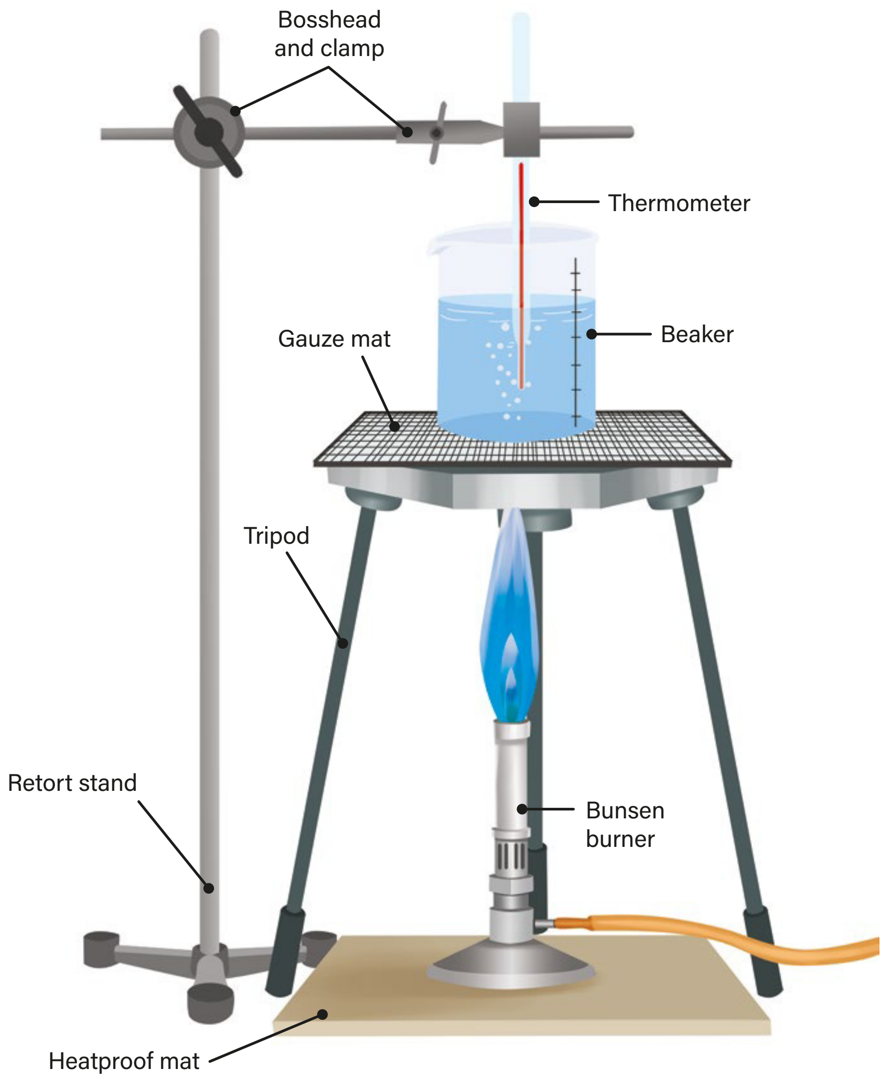


Figure INV1.9: For this investigation, set up the materials as shown in this diagram.

Investigation 2.2

120 min

Classifying items

Inquiry skill: Planning and conducting

Inquiry skill focus: Generating and recording data

In first-hand investigations, qualitative data can be collected. This means that the data is recorded using written descriptions and observations, rather than numbers. To ensure that your data is precise, you must record detailed, specific descriptions of the size, shape, colour and other features of your selected organisms.

Hint 1: How can you record qualitative data?

Hint 2: How can you ensure that the data you have recorded is precise?

Aim

To investigate different ways of classifying living things

Materials

For each group:

- camera
- 20 pieces of paper

Method

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Visit an area near your school or home where there are animals and plants. This could be a natural space, such as a beach or an area of bushland, or a built space, such as a park.
3. Record at least 10 different plants that you find in the area. Photograph each one, if possible.
4. Record at least 10 different animals that you find in the area. Photograph each one, if possible. If the animals belong to other people, such as pets being walked, ask permission before taking a photo.
5. In class, print each photo and label it with the name of the organism, or write the name of each animal or plant you recorded on a separate piece of paper.
6. Sort the organisms you found into three to five different groups. The organisms in each group should have at least one thing in common.
7. Fill in your results table.

Questions

1. Identify a process you used to conduct this investigation. For example, how did you record the plants you found?
2. What scientific equipment did you use in this investigation? How did it help you to gather data?
3. Explain one risk associated with this investigation. How did you minimise the chances of this risk causing harm?
4. How did you make sure that the data you recorded was precise?
5. Explain how the information you gained through your observations could help your local council to maintain the area you visited.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Figure INV2.2: Plants can be classified by their leaves.

DO NOT TOUCH ANY PLANTS OR ANIMALS DURING YOUR INVESTIGATION. THEY COULD BE HAZARDOUS.

Table INV2.2: Results

Group number	Organisms in the group	Features shared by the organisms in the group

Investigation 2.4

120 min

Classifying supermarket items

Inquiry skill: Planning and conducting

Inquiry skill focus: Distinguishing between variables

An important part of scientific investigations is being able to identify the variables. A good investigation has a single independent (changed) variable and a single dependent (measured) variable. All other variables are controlled.

Hint 1: *What one factor are you changing in this investigation?*

Hint 2: *What are you keeping the same? How are you achieving this?*

Aim

To investigate the design and use of classification keys

Materials

For each group:

- ruler
- pen
- supermarket items (first-hand observations or photos)

Method

1. Working in pairs, select one of the following groups of supermarket items:
   - fruits and vegetables
   - dairy items
   - bakery items
   - snack foods.
2. Design a classification system for the items in the group. Your key should include four levels of classification.
3. Visit a supermarket and apply your key to 20 different items. Record how each item is classified according to your key.

Questions

1. Is your classification key a branching key or a dichotomous key? Explain your answer.
2. Use a digital technology to present your classification of the 20 items.
3. Identify the changed, measured and controlled variables from this investigation. Describe how they helped you to construct your classification key.
4. Consider the items you have classified. How similar are they? Record their prices. Suggest which items would be most suitable for a family shopping on a budget to purchase. Justify your item choices.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Figure INV2.4: How could fruits and vegetables be classified based on their physical characteristics?

Investigation 2.5

45 min

Investigating features of marine animals

Inquiry skill: Communicating

Inquiry skill focus: Preparing representations to communicate findings

First-hand investigations can allow scientists to collect data about different organisms by observing them. They must then communicate this data using appropriate scientific structures so that it can be easily understood.

Hint: Which classification tools have you learnt about that could help you to organise your findings?

Aim

To investigate the physical and skeletal features of different marine animals

Materials

For each student:

- safety glasses
- nitrile gloves
- disposable apron

For each group:

- 1 whole fish
- 1 large whole prawn
- 1 squid
- 3 dissecting boards
- magnifying lens
- dissecting kit (dissection scissors, blunt forceps and 2 blunt probes)

Method

1 Working in groups of three or four, put on an apron, gloves and safety glasses, then place the fish, prawn and squid on separate dissection boards.

2 Observe the external features of the fish and record your observations.

3 Open the fish's mouth and look inside, using the magnifying lens to magnify the details. While looking in the mouth, use a dissection probe to open the gill covers on the head. Record your observations.

Figure INV2.5: Using scientific tools can improve our observations of organisms such as this fish.

4 Carefully cut open the fish lengthwise so you can see its skeleton. Record your observations.

5 Use a probe to open the prawn's mouth. Look inside through the magnifying lens. Try to identify whether the prawn has gills and, if so, where they are located. Record your observations.

6 Feel the outside of the prawn, then peel it and cut it in half. Record your observations.

7 Use a probe to open the squid's mouth. Look inside through the magnifying lens. Try to identify whether the squid has gills and, if so, where they are located. Record your observations.

8 Feel the outside of the squid, then peel the skin off and cut the squid in half. Record your observations.

Questions

1 a Which of the three marine animals are vertebrates (with skeletons)?

b Which of the three marine animals are invertebrates (without skeletons)?

2 How did using the magnifying lens improve your observations of the three marine animals?

3 Draw three diagrams showing the three marine animals. Show and label the external and internal features of each specimen.

4 How are the gill structures of the three marine animals different?

5 Identify one physical feature that all three marine animals share.

6 Construct a classification key to sort these three marine animals based on the skeletons and gills.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

WEAR SAFETY GLASSES AND GLOVES. BE CAREFUL WHEN USING CUTTING IMPLEMENTS. DISPOSE OF ALL MATERIALS AS DIRECTED BY YOUR TEACHER. WASH YOUR HANDS AFTER THE INVESTIGATION.

Investigation 2.7

30 min

Investigating structural adaptations

Figure INV2.7: The common snake-necked turtle has many structural adaptations.

Inquiry skill: Questioning and predicting

Inquiry skill focus: Making predictions

It is important to consider research, and our own prior knowledge, when making predictions. Predictions form the basis of scientific hypotheses, so you can start by drawing on what you already know or have observed.

Hint 1: What organisms share common features?

Hint 2: What do you think is similar about the diet or habitat of these organisms?

Aim

To investigate the structural adaptations of different organisms

Materials

For each group:

- a range of preserved specimens
- magnifying lens

Method

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Select five specimens to inspect.
3. Write the name of each specimen in the results table.
4. Use the magnifying lens to observe the features of each specimen.
5. For each specimen, identify one structural adaptation. Record this information in the results table.
6. Why does the organism have this structural adaptation? Record a reason in the results table.

Questions

1. Look at Figure INV2.7. Identify one structural adaptation.
2. Describe how using the magnifying lens improved your observations of your chosen specimens.
3. Describe why it was important to be able to collaborate effectively with other students in your class when completing this activity.
4. What can you predict about how the turtle in Figure INV2.7 uses the adaptation you identified in Question 1? Explain why you made this prediction.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Table INV2.7: Results

Name of organism	Organism's structural adaptation	How the structural adaptation helps the organism to survive

Investigation 3.1

30 min

Identifying community members in a terrestrial ecosystem

Inquiry skill: Communicating

Inquiry skill focus: Presenting scientific findings

Scientists can use a variety of representations to simplify and explain ideas. Visual communications make things easier to understand, which helps us to interpret scientific ideas and findings. As you complete this investigation, think of ways you could present your findings to a group of primary school students.

Hint 1: How long might organisms be happy in a simulated environment?

Hint 2: What types of visuals are easy to transport to multiple locations?

Hint 3: Refer to 'Communicating' in the Science how-to section on page 245.

Aim

To investigate different species in a terrestrial (land-based) ecosystem

Materials

For entire class:

- 4 witches hats (optional)
- species identification resources for your area

For each group:

- thick gardening gloves
- magnifying lens
- coloured pencils

Method

1 Copy the results table into your notebook, adding a title and rows as needed.

2 Select a small ecosystem at your school, no larger than 20 metres by 20 metres. You can mark out an area using witches hats or other physical markers.

3 In the results table, list all the different plants in the ecosystem.

4 Put on the gloves.

5 Use the magnifying lens to look for small organisms living on the plants. Look on the underside of leaves, and in the branches and grass. Add the names of the organisms you find to the results table.

6 Look for more small organisms by carefully turning over fallen leaves and looking under rocks and in the soil. Add the names of the organisms you find to the results table.

7 Sit quietly and identify the different organisms you can see and hear in the ecosystem. Add the names of these organisms to the results table.

8 a Draw each organism you identified.

b Make note of any interesting behaviour or relationships between the organisms that you observed.

Table INV3.1: Results

Location: ____________________

Date: ____________ Time: ____________

Organism name	Drawing of the organism	Observations of behaviour, including any relationships observed

Questions

1 Identify each organism in the results table as a producer, consumer or decomposer.

2 What types of relationships between organisms did you observe?

3 Identify and describe one ethical consideration for this investigation. Discuss your perspective.

4 Describe how you could communicate the findings of this investigation in a visual yet ethical way.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Investigation 3.3

45 min

Measuring abiotic factors

Inquiry skill: Evaluating

Inquiry skill focus: Identifying investigation errors and assumptions

Investigations in a school laboratory are never perfect. There are usually assumptions that are made, and unavoidable errors in the method that impact the results and must be acknowledged. What assumptions and errors are present in this investigation?

Hint 1: *Are we assuming that this investigation replicates the natural environment?*

Hint 2: *Are there factors that are difficult to keep consistent from one test to the next?*

Hint 3: *Refer to 'Evaluating' in the Science how-to section on page 239.*

Aim

To investigate the abiotic factors in a terrestrial (land-based) ecosystem

Materials

For each group:

- thermometer
- trowel
- soil multiprobe (pH, light, moisture)

Method

1 Copy the results table (on the next page) into your notebook, adding a title.

2 Select a small ecosystem in your school.

3 Measure the air temperature 1 metre above the ground in the sunlight by holding the thermometer in the air for several minutes until the reading stabilises. Record the air temperature in the sunlight in the results table.

4 Measure the air temperature 1 metre above the ground in the shade. Record the air temperature in the shade in the results table.

5 Measure the temperature of the surface of the soil by carefully placing the end of the thermometer in the leaf litter or on top of the soil. Leave the thermometer for a few minutes to stabilise. Record the surface soil temperature in the results table.

6 Measure the temperature of the soil 5 cm below the surface. Use the trowel to carefully bury the thermometer bulb about 5 cm deep. Leave the thermometer for a few minutes to stabilise. Record the soil temperature in the results table.

7 Measure the soil moisture 5 cm below the surface. Switch the soil multiprobe to the 'moisture' setting. Carefully push the end of the probe about 5 cm into the soil. Leave the probe for a few minutes to stabilise. Record the soil moisture value in the results table.

8 Measure the pH of the soil 5 cm below the surface. Leave the multiprobe in the soil and carefully switch the setting to 'pH'. Leave the probe for a minute to stabilise. Record the soil pH value in the results table.

Figure INV3.3a:
In this investigation, you will use a multiprobe like this one.

continues ▶

9 Measure the light intensity in the soil 5 cm below the surface. Leave the multiprobe in the soil and carefully switch the setting to 'light/LUX'. Leave the probe for a minute to stabilise. Record the soil light intensity value in the results table.

10 a Use the trowel to collect a soil sample from about 5 cm deep.

b In the results table, describe the soil colour and texture. Is it coarse, gritty or fine? Does it contain organic matter? You may wish to view the sample under a microscope.

Table INV3.3: Results

Air temperature in the sunlight (°C)	
Air temperature in the shade (°C)	
Soil temperature, surface (°C)	
Soil temperature, 5 cm deep (°C)	
Soil moisture, 5 cm deep	
Soil pH, 5 cm deep	
Light intensity, 5 cm deep (LUX)	
Soil colour	
Soil texture	

Questions

1 Compare your results with those of your classmates. Did you and your classmates conduct your investigations in the same or different parts of your school? How might this have affected the results each student obtained?

2 Propose how your results might be different if you repeated this investigation at night, 6 hours earlier or later, or in 6 months.

3 a Research the temperature, light, water and soil requirements of at least two plant species in the same ecosystem.

b How do these values correlate with your results?

4 a Identify and describe any errors in the method.

b Propose how they impacted your results.

c Investigate whether your findings match scientific theory.

d Consider your responses to parts **b** and **c** of this question. Identify and discuss any links.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Figure INV3.3b: A typical school-yard ecosystem

Investigation 3.5

30 min

Algal balls

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Identifying and discussing trends in data

Scientists analyse the data they collect by identifying and assessing any trends or patterns. These trends can help to explain the relationship between variables.

Hint: *Refer to 'Processing, modelling and analysing' in the Science how-to section on page 230.*

Aim

To investigate, using algal balls, how different light levels affect the rate of photosynthesis

Materials

For each group:

- algal balls
- 4 small sample jars with lids
- 10 mL measuring cylinder
- hydrogen carbonate indicator solution (0.0025% bromothymol blue works as an alternative)

Method

1. Copy the results table into your notebook, adding a title.
2. Carefully place an equal number of algal balls (approximately 10–20) in each sample jar.
3. Use the measuring cylinder to measure an equal amount of hydrogen carbonate indicator solution into each sample jar, ensuring the algal balls are covered.
4. Place the lids on the jars.
5. Place the jars in different places around your classroom that get different amounts of sunlight. They could be placed on a windowsill, on a shelf away from the window or in a cupboard.
6. Leave the jars until the next day.
7. Compare the colour of each solution to the colour indicator chart (Figure INV3.5).
8. Record the results of this investigation in the results table.

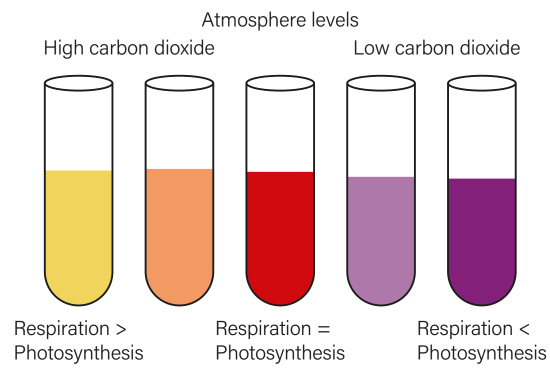


Figure INV3.5: Hydrogen carbonate indicator colour chart

9. Rank the sample jars from 1 to 4. Jar 1 is the one in which the *most* photosynthesis took place, and jar 4 is the one in which the *least* photosynthesis took place. Write your rankings in the results table.

Table INV3.5: Results

Sample jar location	Colour	pH	Rank (1–4)

Questions

1. Identify three hazards present in this investigation. Describe how you minimised the risk for each.
2. Consider the photosynthesis reaction.
   a. Identify the reactants and products.
   b. Identify what else is required.
3. a. Identify which sample jar had the lowest and highest pH measure.
   b. Propose what this suggests about the amount of photosynthesis that took place.
4. a. Construct a chart or graph to represent your data. See the Science how-to section on page 232 if you need help.
   b. Identify any patterns or trends in your data.
   c. Propose what the patterns or trends suggest about the relationship between variables.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Investigation 4.1

15 min

Compressing liquids and gases

Inquiry skill: Planning and conducting

Inquiry skill focus: Distinguishing between variables

In an investigation, there should be one independent (changed) and one dependent (measured) variable. This is to make sure that the changed variable is responsible for any changes in what we measure.

Hint 1: *What are we changing and measuring in this investigation?*

Hint 2: *Refer to step 3, 'Planning and conducting investigations', in the Science how-to section on page 226.*

Aim

To investigate how much a liquid and a gas can be compressed

Materials

For each group:

- 100 mL beaker
- tap water
- plastic syringe

Method

1. Copy the results table into your notebook, adding a title.
2. Fill the beaker with water.
3. Draw some water from the beaker into the syringe so that it is about half full.
4. Hold your finger over the nozzle of the syringe so that water cannot come out, then try to push in the plunger. Are you able to compress the water? Record your observations in the results table.
5. Empty the water from the syringe and pull back the plunger so that the syringe is half full of air.
6. Again, hold your finger over the nozzle of the syringe and try to push in the plunger. Are you able to compress the air? Record your observations in the results table.

Questions

1. For this investigation, identify:
   a. the independent variable.
   b. the dependent variable.
   c. two controlled variables.
2. Describe what the results tell you about how much liquid can be compressed (compressibility).
3. Describe what the results tell you about the compressibility of gases.
4. Explain the results you recorded, with reference to the particles of liquids and gases.
5. Propose how you could investigate the compressibility of solids using an ice cube.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Table INV4.1: Results

Material	Initial reading (mL)	Final reading (mL)	Difference in size (mL)

Figure INV4.1: In this investigation, you will use a syringe to try to compress a liquid and a gas.

Investigation 4.2

Heating materials

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Organising data

In this investigation, it is important to record your data and observations using a suitable table. Before you start your investigation, design a table with appropriate columns and rows to record your data and observations.

Hint 1: *Use a ruler to draw your table so it is neat, clear and easy to read.*

Hint 2: *Refer to the Science how-to section on page 230.*

Figure INV4.2: ▶ For this investigation, place three spoons into hot water, handle-side down.

Aim

To investigate how quickly different materials can heat up

Materials

For each group:

- 3 large spoons (one metal, one wooden, one reusable plastic)
- wax (e.g. from a candle) or butter
- 500 mL beaker
- hot water from tap
- stopwatch

Method

1. Scoop a small amount of wax on to each spoon.
2. Half fill the beaker with hot water from the tap. Place all three spoons into the water, handle-side down. Start the stopwatch.
3. Continuously watch the spoons, recording any qualitative observations.
4. When the wax melts off each spoon, note and record the time.

⚠ **HOT WATER IS A HAZARD. TAKE CARE WHEN HANDLING IT. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES.**

Questions

1. a Identify the following statement as true or false: 'All the spoons are solid, so their particles must all have the same amount of kinetic energy (motion).'
   b Provide a reason for your response, with reference to the particle and kinetic theories of matter.
2. a Describe what you did to minimise your risk of being burnt by hot water in this experiment.
   b Describe anything else you could have done to minimise the risk.
   c Outline what you would do if you spilled the hot water on your hand.
3. a Identify the independent (changed) and dependent (measured) variables in this experiment.
   b Construct a column graph to show how long it took each type of spoon to melt the wax. *Hint:* Your dependent (measured) variable should be on the y-axis.
4. Propose a piece of equipment that would allow you to measure the average kinetic energy of each spoon.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

30 min

Expanding gases

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Identifying data

When conducting investigations, it is important to identify the type of data that can be collected. It can then be recorded in an organised way, which will lead to the finding of the investigation. Read the method for this investigation and determine the type of data you will be collecting.

Aim

To investigate how the volume of a gas changes when heated

Materials

For each group:

- balloon
- conical flask
- string
- pen
- ruler
- 2 beakers (large enough to fit the conical flask inside)
- iced water
- hot water from tap

Method

1 Inflate and deflate the balloon a couple of times to stretch it out.

2 Blow up the balloon so that it has a diameter of about 10 cm. Place the balloon over the neck of the conical flask.

3 Wrap the string around the widest part of the balloon and mark the string where the two parts touch. Unwrap and measure the string with a ruler. Record the circumference of the balloon at room temperature.

HOT WATER IS A HAZARD. TAKE CARE WHEN HANDLING IT. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES.

Figure INV4.3: For this investigation, set up the materials as shown in this diagram.

4 Half fill one of the beakers with iced water and place the conical flask inside the beaker. Let it stand for 5 minutes.

5 Use the string to measure the circumference of the balloon after the air has been cooled by the water and record the measurement.

6 Transfer the conical flask to the beaker containing hot water. Let it stand for 5 minutes.

7 Use the string to measure the circumference of the balloon after the air has been warmed by the water and record the measurement.

Questions

1 Describe the effect that heating had on the circumference of the balloon.

2 Use the particle model to explain why this happened.

3 Predict what you would expect to happen to the circumference of the balloon if the water was heated further.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Investigation 4.4A

45 min

Changing states of water

Inquiry skill: Questioning and predicting

Inquiry skill focus: Constructing scientific questions

Turn the aim of this investigation into a question that asks what you are trying to discover. This is called a research question.

Hint 1: *Your research question can also be used as a title for a scientific report.*

Hint 2: *Make sure that your research question has a question mark at the end.*

Aim

To determine the temperature of water at each change of state

Materials

For each group:

- heatproof gloves
- 1 cup full of ice cubes
- 250 mL beaker
- tap water
- heatproof mat
- Bunsen burner
- tripod
- gauze mat
- retort stand
- bosshead and clamp
- thermometer (or data logger with temperature probe)
- matches
- stopwatch

Method

1. Copy the results table (on the next page) into your notebook, adding a title.
2. Add ice cubes up to the 100 mL mark on the beaker.
3. Add water to the beaker so that it surrounds the ice cubes up to the 100 mL mark.
4. Use the thermometer to measure the temperature of the water. Record this information in the results table.

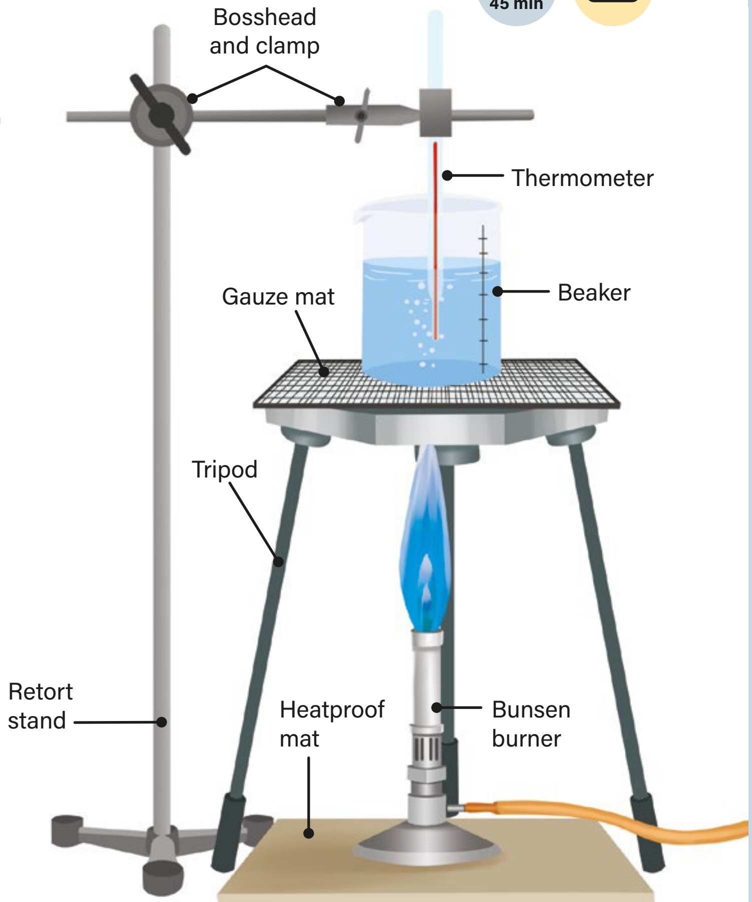


Figure INV4.4A: For this investigation, set up the materials as shown in this diagram. Make sure the thermometer does not touch the beaker!

5. Set up the thermometer, Bunsen burner, tripod, heatproof mat, gauze mat, retort stand and clamp (see Figure I4.4A).
6. Light the Bunsen burner and turn to the blue flame. Heat the water. Ensure the collar of the Bunsen burner is turned so the airhole is open. Start timing immediately with the stopwatch.
7. Use the thermometer to measure the temperature of the water every 30 seconds. Record this temperature in the results table.

AN OPEN FLAME AND BOILING WATER ARE HAZARDS. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES.

continues ▶

8 Continue measuring and recording the temperature of the water until the liquid has boiled for 3 minutes. Ensure you turn off the Bunsen burner.

9 The beaker, gauze mat and other heated equipment will be very hot. Leave the equipment to cool and only handle while using heatproof gloves.

Table INV4.4A: Results

Time (seconds)	Temperature (°C)	Observations
0		
30		
60		
90		
120		
150		
180		

Questions

1 a **Hazards:** Identify three things that could harm the person conducting this investigation.

b **Risks:** Decide whether you think there is a low, medium or high chance that each hazard will harm the person conducting this investigation.

c **Management strategies:** Identify steps you can take to make sure each hazard does not harm the person conducting this investigation.

2 Identify three pieces of equipment you needed in order to successfully conduct this investigation. Explain why you needed each item.

3 For this investigation, identify:

a the independent variable.

b the dependent variable.

c two controlled variables.

4 Construct a graph with temperature on the *y*-axis. If you need help, refer to page 232 in the Science how-to section.

5 a Identify the temperature of the water when the ice completely melted.

b Propose whether this is the melting point of water. Explain your response.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation **4.4B**

60 min

Exploring melting points

Inquiry skill: Questioning and predicting

Inquiry skill focus: Making predictions

A key component of first-hand investigations is making a prediction of the expected outcome of the investigation. Before you begin, predict the order in which the liquids will melt and boil.

Hint: *Base your predictions on what you already know or have observed.*

Aim

To investigate the melting and boiling points of different household substances

Materials

For each group:

- heatproof gloves
- 4 types of household liquids (e.g. vinegar, dishwashing liquid, cooking oil, milk)
- ice-cube tray (to make ice cubes)
- 4 50 mL beakers
- heatproof mat
- Bunsen burner
- tripod
- gauze mat
- large beaker
- tap water
- matches
- thermometer

Table INV4.4B: Results

Sample	Melting point	Boiling point

OPEN FLAMES, HOT LIQUID, WAX AND STEAM ARE HAZARDS. TAKE CARE. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES.

Method

1. The day before the investigation, pour each substance into a separate ice-cube mould. Place the trays in a freezer overnight.
2. Collect your solid, frozen samples.
3. Copy the results table into your notebook, adding a title.
4. Set up the Bunsen burner, tripod and gauze mat.
5. Half fill a large beaker with water. This will act as your water bath for the samples.
6. Remove one of the samples from the ice-cube tray and place it into a small beaker. Place the small beaker into the large beaker.
7. Light the Bunsen burner beneath the beaker and change to a blue flame. Heat the sample until it has completely melted. Use the thermometer to measure the melting point of the sample and record it in your table.
8. If time permits, continue to heat the sample until it begins to boil.
9. Use the thermometer to measure the boiling point of the sample and record it in your table.
10. Repeat steps 6–9 for the rest of your samples.

Questions

1. Identify the substances with the lowest and highest melting points.
2. Identify the substances with the lowest and highest boiling points.
3. Discuss your results in relation to your predictions.
4. Consider the classroom you are currently in. Can you identify something in the room that would have a very high melting point? Justify your answer.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Investigation 4.5

Exploring density

Inquiry skill: Planning and conducting

Inquiry skill focus: Generating and recording data

A good investigation involves collecting accurate and precise data. The data collection process must be planned to ensure consistency and organisation, including the type of equipment used to take measurements.

Hint 1: *How does the equipment used in this experiment let you collect exact values?*

Hint 2: *Refer to the Science how-to section on page 280.*

Aim

To investigate the relative densities of various household liquids and objects

Materials

For each group:

- safety glasses
- nitrile gloves
- digital scales
- 50 mL measuring cylinder
- water (with food dye, to make it easier to see)
- honey
- corn syrup
- dishwashing liquid
- isopropyl alcohol
- vegetable oil
- salt water

Method

1. Copy the results table (on the next page) into your notebook, adding a title.
2. Use the digital scales to weigh the empty 100 mL measuring cylinder. Record its mass in grams in your notebook.
3. Pour 100 mL of water into the measuring cylinder. In the results table, record the volume of the water in millilitres.
4. Weigh the measuring cylinder with the water. Be careful not to spill the water. In your notebook, record its mass in grams.
5. Work out the mass of the water by subtracting the weight of the empty measuring cylinder. In the results table, record the mass of the water.
6. Thoroughly clean and dry the measuring cylinder, then repeat steps 2–5 with the other substances.

WEAR SAFETY GLASSES AND NITRILE GLOVES WHEN HANDLING ISOPROPYL ALCOHOL. DISPOSE OF OILS AND ALCOHOLS CORRECTLY.

Figure INV4.5: When substances of different densities are placed in the same container, the less dense substances stay at the top and the most dense substances settle at the bottom. ▶

Questions

1 Identify which pieces of equipment you needed in order to successfully conduct this investigation. Explain why you needed each item.

2 For this investigation, identify:

- **a** the independent (changed) variable.
- **b** the dependent (measured) variable.
- **c** two controlled variables (kept the same).

3 Rank the liquids from most dense to least dense.

4 If you placed all the liquids in one container (as in the image in Figure INV4.5), predict the order they would settle in, based on your results. Explain the reason for your prediction.

5 **a** Calculate the density of each substance. Record this information in the results table.

b Identify whether the densities you calculated in Question 5a matched the SI values in the last column of the table. Give a reason you might have calculated different values. (Hint: Think about your controlled variables.)

6 Propose which substance has the highest viscosity. The lowest? Explain your responses.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table INV4.5: Results

Substance	Volume (mL)	Mass (g)	Density from experiment $\left(\frac{\text{mass}}{\text{volume}}\right)$	Density SI value (g/mL)
Water				1.000
Honey				1.440
Corn syrup				1.370
Dishwashing liquid				1.200
Isopropyl alcohol				0.789
Vegetable oil				0.910
Salt water				1.150

Note: SI stands for the International System of Units, which are the standard measurements used by scientists around the world.

Investigation 4.6A

45 min

Water as a solvent

Inquiry skill: Questioning and predicting

Inquiry skill focus: Making predictions

A key component of first-hand investigations is making a prediction of the outcome of the investigation. You may not know much about the science of the substances under investigation, so sometimes it is okay to make a prediction based on what you already know and have observed.

Before you begin, predict which substances will dissolve in water.

Hint: Base your predictions on what you already know or have observed.

Aim

To investigate which substances dissolve in water

Materials

For each group:

- 5 x 100 mL beakers
- masking tape
- marker pen
- 100 mL measuring cylinder
- tap water
- spatula
- digital scales
- watch glass or filter paper (to weigh each substance)
- 5 g table salt (sodium chloride ($NaCl$))
- glass stirring rod
- 5 g sugar (sucrose)
- 5 g baking soda (sodium hydrogen carbonate ($NaHCO_3$))
- 5 g chalk (calcium carbonate ($CaCO_3$))
- 5 g sand

Method

1 Copy the results table into your notebook, adding a title.

2 Label the beakers 1–5 using masking tape and a marker pen.

3 Use the measuring cylinder to measure 50 mL of water into each beaker.

4 Use the spatula and the digital scales to measure 5 g of salt. Add the salt to beaker 1. Stir the mixture with the stirring rod.

Figure INV4.6A: Make sure your digital scales read 0 (zero) before measuring the 5 g of each substance.

5 Observe whether the salt dissolves. Record this information in the results table by placing a tick in the 'Soluble in water' or 'Insoluble in water' column.

6 Repeat steps 4 and 5 for the other substances.

Table INV4.6A: Results

Beaker number	Substance	Soluble in water	Insoluble in water
1	Salt		
2	Sugar		
3	Baking soda		
4	Chalk		
5	Sand		

Questions

1 For the beakers in which you observed a solution, identify the solute and solvent.

2 Identify the pieces of equipment you needed in order to successfully conduct this investigation. Explain why you needed each item.

3 For this investigation, identify:

a the independent variable.

b the dependent variable.

c two controlled variables.

4 Evaluate your prediction. Does it match your results? Discuss.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Investigation **4.6B**

60 min

Solubility and temperature

Inquiry skill: Questioning and predicting

Inquiry skill focus: Developing a hypothesis

Part of a scientific investigation includes developing a hypothesis, which is a proposed prediction of the outcome of an investigation intended to address a problem or answer a question. Develop a hypothesis for this investigation, using the format below.

If …, then …, because …

Hint 1: *What do you know about the relationship between solubility and temperature?*

Hint 2: *How can the particle and kinetic theories of matter inform your prediction?*

Hint 3: *For help, refer to the Science how-to section on page 225.*

Aim

To investigate which substances dissolve in water at different temperatures

Materials

For each group:

- masking tape
- marker pen
- 4 100 mL beakers
- measuring spoons
- table salt (sodium chloride ($NaCl$))
- sugar (sucrose)
- sodium hydrogen carbonate ($NaHCO_3$)
- sand
- 50 mL measuring cylinder
- 250 mL of 20 °C tap water in a large beaker
- 250 mL of 40 °C tap water in a large beaker
- thermometer
- stirring utensil (spoon or stirring rod)
- stopwatch

Method

1. Copy the risk assessment table (on the next page) into your notebook.
   a. **Hazards:** Identify three things that could harm the person conducting this investigation.
   b. **Risks:** Decide whether you think there is a low, medium or high chance that each hazard will harm the person conducting this investigation.
   c. **Management strategies:** Identify steps you can take to make sure each hazard does not harm the person conducting this investigation.
2. Copy the results table (on the next page) into your notebook, adding a title.
3. Use masking tape and a marker pen to label four beakers as ‘salt’, ‘sugar’, ‘baking soda’ and ‘sand’.
4. Add 1 teaspoon of salt to the beaker labelled ‘salt’. Repeat for the other three substances (1 teaspoon of each into the appropriate beaker).
5. In your notebook, record the appearance of each substance. Note the colour, texture and any other observable characteristics.
6. Adjust the temperature of the water in one 250 mL beaker to 20 °C by adding hot or cold water. Confirm the temperature using the thermometer.
7. Use a measuring cylinder to add 50 mL of water to each small beaker. Start the stopwatch.
8. Stir gently with a spoon to see if the substances dissolve.
9. In the results table, record which substances dissolve and which do not.
10. For substances that dissolve, record the time it takes for them to dissolve completely.
11. Repeat steps 3–9 using water at 40 °C.

continues ▶

Questions

1 Describe how effective your risk minimisation strategies were during this investigation.

2 For each substance, compare its initial appearance with its appearance mixed in water. What changes did you observe?

3 a For the substances that dissolved, use the data to construct an appropriate graph of solubility at different temperatures, with temperature on the *x*-axis and the amount of solute on the *y*-axis.

  b Based on the trends in the graph, identify the relationship between solubility and temperature.

4 Compare your hypothesis to the investigation findings and discuss.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table INV4.6Ba: Risk assessment

Hazard	Risk (low, medium, high)	Management strategy

Table INV4.6Bb: Results

Substance	Observed characteristics	Water at 20 °C		Water at 40 °C	
		Dissolve or not dissolve	Time taken to dissolve (s)	Dissolve or not dissolve	Time taken to dissolve (s)
Salt					
Sugar					
Baking soda					
Sand					

45 min

The Tyndall effect

Inquiry skill: Planning and conducting

Inquiry skill focus: Generating and recording data

A good investigation involves collecting accurate and reliable data. The data collection process must be planned to ensure consistency and precision.

Hint 1: *Ensure you can identify the specific data you are recording/measuring (the dependent variable), and how you are doing this.*

Hint 2: *Ensure that the data collection is consistent and fair. Think about how to undertake each test in a consistent manner to ensure accuracy when comparing samples.*

Hint 3: *Suspension: a mixture in which larger particles settle over time; colloid: a mixture in which smaller particles remain suspended and do not settle over time.*

Hint 4: *Refer to 'Planning and conducting' on page 226 of the Science how-to section.*

Aim

To identify three types of mixtures – solutions, suspensions and colloids – by using the Tyndall effect

Materials

For each group:

- test tube rack
- 7 labelled test tubes containing prepared mixtures of pure water and the following substances:
  - milk
  - soluble starch
  - food colouring
  - sugar
  - flour
  - sodium chloride (table salt)
- glass stirring rod
- torch

Method

1. Copy the results table into your notebook, adding a title.
2. Set up the mixtures.
3. a. Use the stirring rod to stir each mixture.
   b. In the results table, record which mixtures separate on standing.
4. Observe the mixtures. Record a description of each mixture in the results table.
5. Make the room as dark as possible or use an under-bench cupboard. For each mixture that does not separate on standing, shine a torch on it. In your results table, describe whether the mixture exhibits the Tyndall effect (it scatters light) (see Figure INV5.1).
6. Classify each mixture as a solution, suspension or colloid. Record these classifications in the results table.

Questions

1. The effect of light scattering by particles is known as the __________ __________.
2. a. If a mixture is left to stand and then separates, it is a __________.
   b. If a mixture does not separate on standing and the Tyndall effect is not seen, the mixture is a __________.
   c. If a mixture does not separate on standing and exhibits the Tyndall effect, the mixture is a __________.
3. What precautions should be taken to ensure safety when performing this investigation, particularly when working in a darkened room and handling glass equipment?
4. Explain how your method for observing and recording the mixtures helps to ensure reliable results.

continues ▶

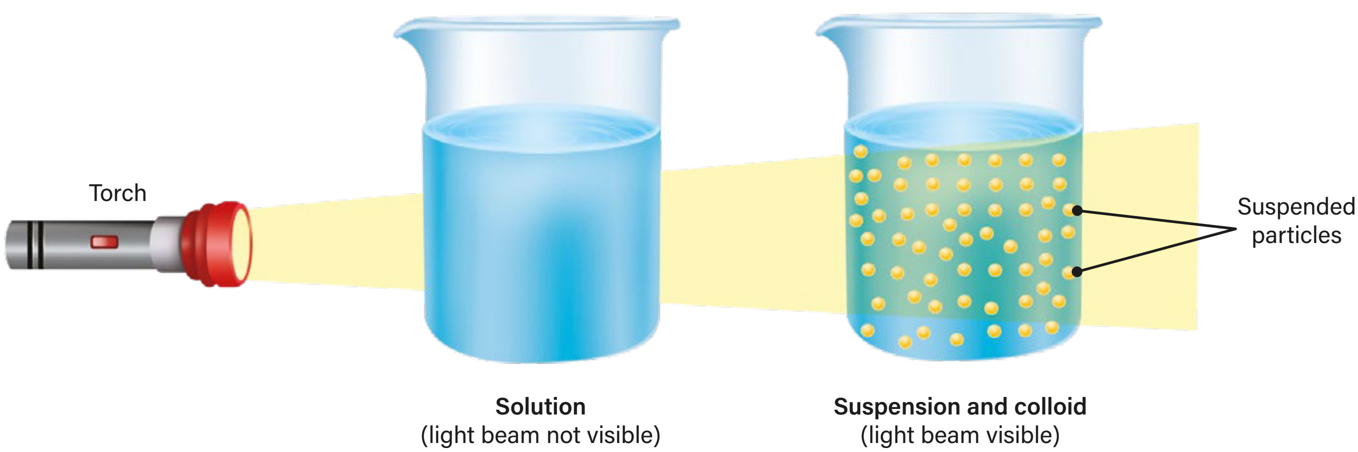
Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table INV5.1: Results

Test tube	Mixture	Brief description	Separates on standing?	Exhibits Tyndall effect?	Classification (solution, suspension or colloid)
1	Milk				
2	Soluble starch				
3	Food colouring				
4	Sugar				
5	Flour				
6	Salt				

Figure INV5.1: Mixtures containing suspended particles display the Tyndall effect (a visible, scattered light beam).



Investigation 5.2

Solutes and solvents

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Identifying data

When conducting investigations, it is important to identify the type of data that can be collected. This data can then be represented using suitable tables and graphs.

Hint: *Refer to 'Processing, modelling and analysing' on page 230 of the Science how-to section.*

⚠ HYDROCHLORIC ACID IS A HAZARD. BE CAREFUL. WEAR SAFETY GLASSES AND GLOVES DURING THIS INVESTIGATION TO PREVENT ACID FROM BURNING YOUR SKIN OR SPLASHING IN YOUR EYES. DISPOSE OF ALL LIQUIDS AS DIRECTED BY YOUR TEACHER.

45 min

Aim

To investigate which liquids will dissolve salt

Materials

For each group:

- safety glasses
- nitrile gloves
- 5 test tubes
- marker pen
- test tube rack
- spatula
- digital scales
- 25 g sodium chloride (table salt) (NaCl)
- filter paper or watch glass (to weigh the salt)
- 50 mL measuring cylinder
- 20 mL tap water
- funnel
- glass stirring rod
- 20 mL 0.1 M hydrochloric acid (HCl) in a small sealed dropper or reagent bottle
- 20 mL oil
- 20 mL milk
- 20 mL 0.1 M sodium hydroxide (NaOH) in a small sealed dropper or reagent bottle

Method

1. Copy the results table into your notebook, adding a title.
2. Put on the safety glasses and gloves.
3. Collect 5 test tubes and label them 1–5 with a marker pen. Place them in a test tube rack.
4. Using the spatula, filter paper or watch glass, and digital scales, measure 5 g of salt into each test tube.
5. Use the measuring cylinder to measure 20 mL of water. Using the funnel, pour the water into test tube 1 and use the stirring rod to stir the mixture.
6. Observe whether the salt dissolves. Record your observations in the results table. If the salt dissolves, place a tick in the 'Salt is soluble' column. If the salt does not dissolve, place a tick in the 'Salt is insoluble' column.
7. Determine whether or not water is a solvent for salt. (If the salt dissolved, water is a solvent for it.) If water is a solvent for salt, place a tick in the 'Acts as a solvent?' column.
8. Repeat steps 4–6 with the other liquids.

Questions

1. Identify whether the data collected in this investigation is qualitative or quantitative.
2. For this investigation, identify:
   a. the independent variable.
   b. the dependent variable.
   c. two controlled variables.
3. For each test tube observed, if the salt dissolved, identify:
   a. the solute.
   b. the solvent.
4. When dissolving salt, propose which liquid is the best solvent. Justify your answer.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Table INV5.2: Results

Test tube	Liquid	Salt is soluble	Salt is insoluble	Acts as a solvent?
1	Water			
2	Hydrochloric acid			
3	Oil			
4	Milk			
5	Sodium hydroxide			

Investigation 5.3A

Calculating the concentrations of solutions

Inquiry skill: Evaluating

Inquiry skill focus: Identifying investigation errors and assumptions

Investigations in a school laboratory are never perfect. There are usually assumptions that are made, as well as unavoidable errors that impact the results and must be acknowledged. What assumptions and errors are present in this investigation?

Hint 1: *Think about any assumptions that may be made, and how these may impact the accuracy of your results.*

Hint 2: *In looking for errors, consider whether there are factors that are difficult to keep consistent from one test to the next.*

Hint 3: *Refer to 'Evaluating' on page 239 of the Science how-to section.*

Aim

To investigate different concentrations of salt solutions

Materials

For each group:

- digital scales
- 50 g sodium chloride (table salt)
- filter paper or watch glass (to weigh the salt)
- 4 × 50 mL beakers
- 50 mL measuring cylinder
- 100 mL tap water
- glass stirring rod
- heatproof mat
- Bunsen burner
- tripod
- gauze mat
- matches

AN OPEN FLAME IS A HAZARD. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES.

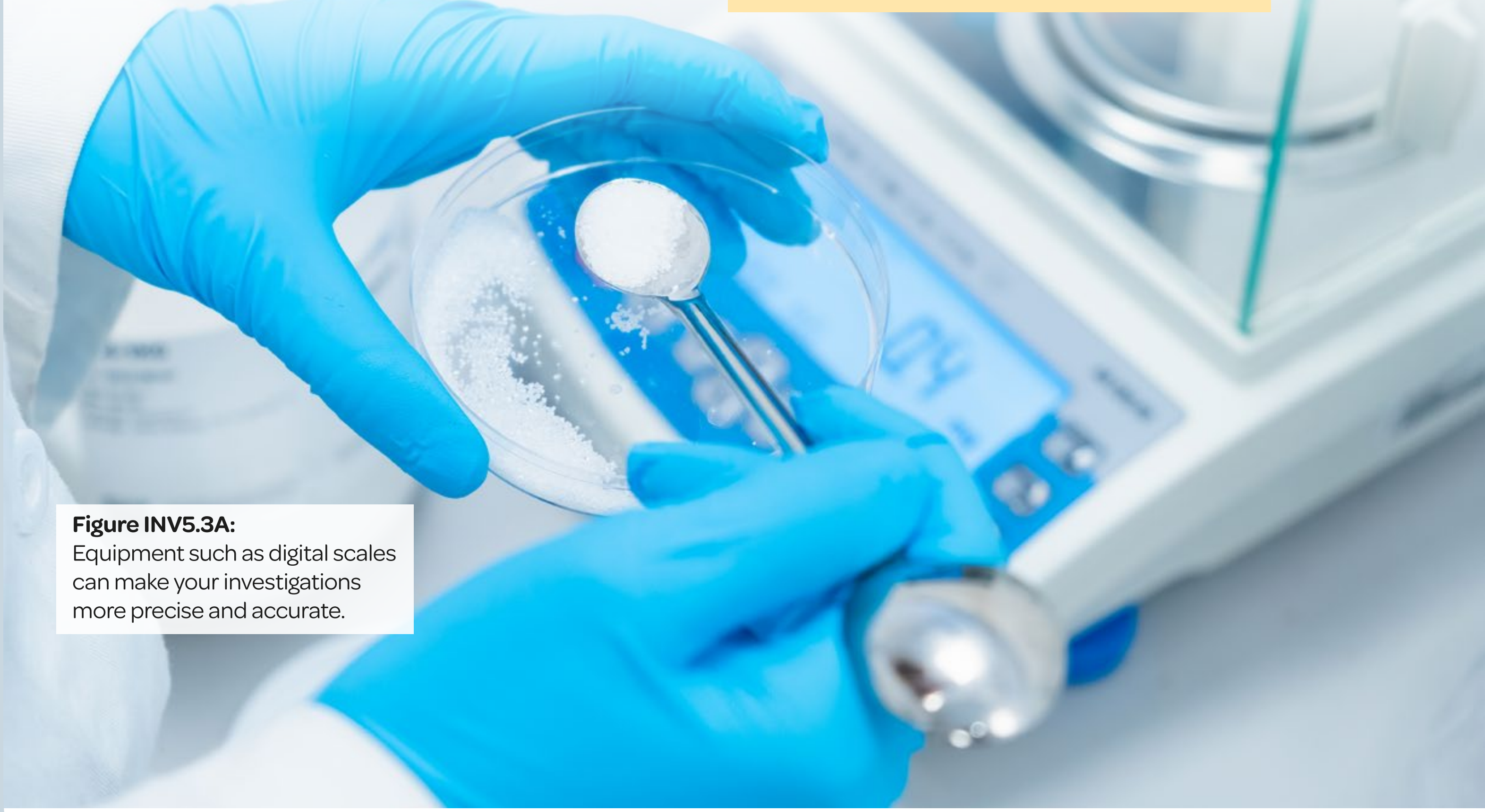


Figure INV5.3A: Equipment such as digital scales can make your investigations more precise and accurate.

60 min

Method

1 Copy the results table into your notebook, adding a title.

2 a Use the filter paper or watch glass and digital scales to measure 5 g of sodium chloride (table salt).

b Place the salt in a beaker.

3 a Use the measuring cylinder to measure 20 mL of water (20 mL = 0.020 L).

b Place the water in the beaker with the salt.

4 Stir the salt and water with a stirring rod until no salt remains visible.

5 If salt is still visible after stirring, place the beaker over a Bunsen burner on a tripod and gauze mat.

6 a Use the matches to light the Bunsen burner and turn to the blue flame.

b Heat the salt and water while stirring with the stirring rod until the salt is dissolved.

7 Allow the solution to cool before removing the beaker from the gauze mat. Observe: Is all the salt still dissolved?

8 Repeat steps 2–7, increasing the mass of salt by 5 g each time, until 20 g of salt has been dissolved to form a salt-water solution.

Questions

1 Describe how you made sure you put the right amount of salt into the beaker.

2 Propose why it is important to use a measuring cylinder to measure the water.

3 Provide three reasons why the data you collected in this investigation was accurate.

4 a At what mass of salt did you require heat to dissolve the salt?

b Which of your solutions were supersaturated solutions? Justify your choice.

5 Using the information in the results table, calculate the concentration of each of your salt-water solutions. Record these values in the results table. *Remember:* We can calculate the concentration of a solution by dividing the mass of the solute by the volume of the solvent. Scientists commonly record concentration in grams per litre (g/L), which is why we need to convert the volume of water from millilitres to litres (divide by 1000). The formula for calculating concentration is $C = \frac{m}{V}$.

6 a Identify and describe any errors in the method.

b Propose how they impacted your results.

c Investigate whether your findings match scientific theory.

d Describe whether the potential errors you identified may have affected the accuracy of your results.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table INV5.3A: Results

Mass of sodium (g)	Volume of water (L)	Salt-water solution concentration (g/L) (mass/volume)
5	0.020	
10	0.020	
15	0.020	
20	0.020	

Investigation 5.3B

30 min

Preparing dilutions

Inquiry skill: Evaluating

Inquiry skill focus: Describing types of errors

Investigations in a school laboratory are never perfect. There are often errors in the method or the equipment that impact the results and must be identified. Acknowledging and describing these types of errors helps in evaluating the validity of the results and in suggesting improvements for future investigations.

Hint 1: *Identify any variables that are difficult to control. Think about how you can try to ensure they are controlled as best as possible.*

Hint 2: *Refer to 'Evaluating' on page 239 of the Science how-to section.*

Aim

To prepare a range of dilutions of cordial and to compare colour intensities

Materials

For each group:

- marker pen
- 6 large test tubes (minimum: 20 mm × 150 mm)
- test tube rack
- 10 mL plastic measuring cylinder
- 30 mL cordial concentrate
- tap water

Method

1. Copy the results table into your notebook, adding a title.
2. Use the marker pen to label the 6 test tubes 1–6. Place the test tubes in a test tube rack.
3. Use the measuring cylinder to accurately measure 10 mL of cordial concentrate and pour it into test tube 1.
4. Use the measuring cylinder to accurately measure 10 mL of water and pour it into test tube 1. Between each trial, rinse the cylinder to remove traces of cordial.
5. For the other test tubes, repeat steps 3 and 4, but change the volume of cordial to:
   - test tube 2: 8 mL cordial; 10 mL water
   - test tube 3: 6 mL cordial; 10 mL water
   - test tube 4: 4 mL cordial; 10 mL water
   - test tube 5: 2 mL cordial; 10 mL water
   - test tube 6: 0 mL cordial; 10 mL water.
6. In the results table, record the colour intensities of the liquids in the test tubes, using the words 'darkest', 'dark', 'light' and 'lightest'.

Questions

1. Identify the steps in using the measuring cylinder to measure the correct amount of cordial and water. (*Hint:* You need to be aware of the meniscus. See 'Observing the meniscus' on page 280 of the Science how-to section.)
2. Describe why failing to rinse the measuring cylinder between trials introduces errors into the experiment, and explain how these errors might affect the results.
3. Describe how this investigation models changes in concentrations of solutions.
4. Which of your solutions is the most concentrated and which is the least concentrated? Justify your answer.
5. During the investigation, errors can occur that impact the precision and accuracy of the results. Describe two types of errors that could occur when preparing the dilutions and how they might affect the results. Suggest ways to minimise these errors.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table INV5.3B: Results

Test tube	Volume of cordial (mL)	Volume of water (mL)	Colour intensity (darkest, dark, light and lightest)
1	10	10	
2	8	10	
3	6	10	
4	4	10	
5	2	10	
6	0	10	

Investigation 5.4

30 min

Purifying muddy water

Inquiry skill: Planning and conducting

Inquiry skill focus: Identifying scientific equipment

Scientific equipment is used for specific purposes during first-hand investigations. In this investigation, how should the materials be used to ensure that the muddy water mixture is properly separated?

Hint 1: *Ensure there are no holes in the filter paper that could allow the residue to pass through.*

Hint 2: *Did you let the mixture settle before decanting?*

Aim

To purify muddy water by decanting and filtration

Materials

For each group:

- 250 mL beaker
- 125 mL tap water
- glass stirring rod
- 250 mL conical flask
- 5 g sand
- 5 g soil
- filter paper
- filter funnel to suit conical flask

Method

1. Copy the results flowchart (on the next page) into your notebook.
2. Half fill the beaker with water.
3. Place the soil into the beaker. Stir with a stirring rod until a suspension forms.
4. Place the sand into the beaker and allow the sand to settle to the bottom.
5. Fold the filter paper as shown in Figure INV5.4a.
6. Set up the filter paper, filter funnel and conical flask as shown in Figure INV5.4b. Place the folded filter paper into the filter funnel. Place the filter funnel into the conical flask.
7. Carefully pour the mixture from the beaker into the conical flask, without disturbing the sand on the bottom of the beaker.
8. Record your observations in the results flowchart (Figure INV5.4c).

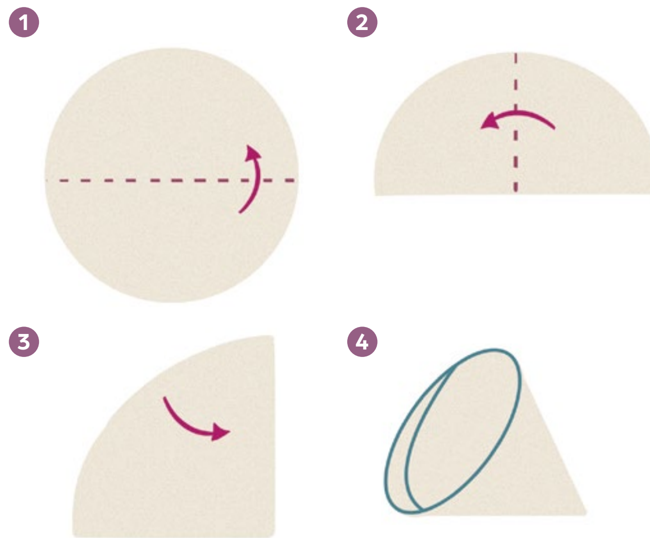


Figure INV5.4a: For this investigation, follow these steps to fold the filter paper: (1) Fold the filter paper in half. (2) Fold it in half again. (3) Open it so it forms a cone shape with three layers on one side and one on the other (4).

Figure INV5.4b: For this investigation, set up the materials as shown in this diagram.

continues ▶

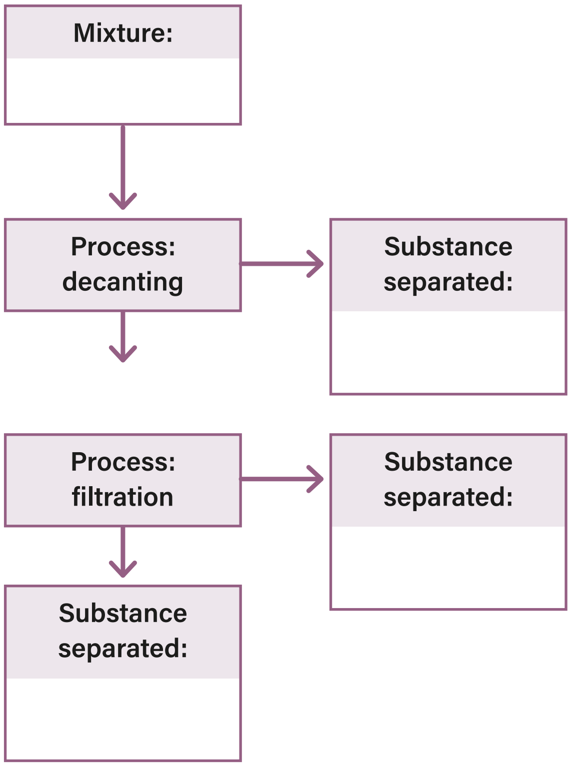


Figure INV5.4c: Results flowchart

Questions

1. Describe how the filter paper enabled you to separate the soil and water.
2. Which pieces of equipment did you need in order to successfully conduct this investigation? Why did you need each item?
3. Identify which component formed the:
   a. suspension.
   b. sediment.
   c. filtrate.
   d. residue.
4. Describe the physical properties that allowed you to separate the soil and the sand.
5. Describe how you minimised at least two risks that are present in this investigation.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Investigation **5.5A**

30 min

Evaporating a solution

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Organising data

In this investigation, it is important to record your data and observations using a suitable table. Before you start your investigation, design a table with appropriate columns and rows to record your data and observations.

Hint 1: Use a ruler to draw your table so it is neat, clear and easy to read.

Hint 2: Refer to 'Processing, modelling and analysing' on page 230 of the Science how-to section.

Aim

To investigate what happens when a solution evaporates

Materials

For each group:

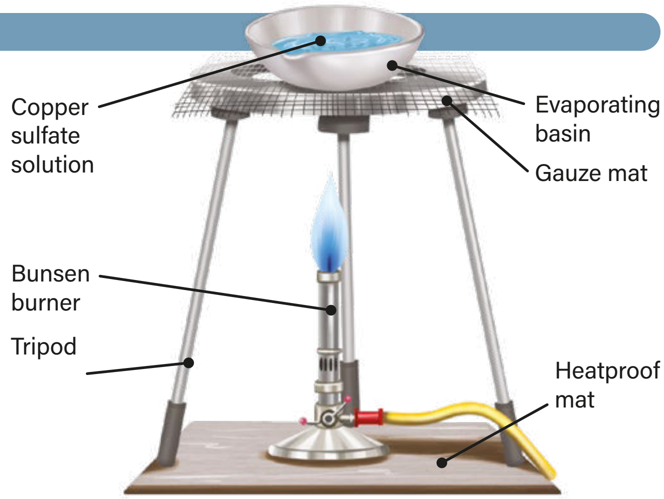
- safety glasses
- nitrile gloves (if needed)
- 5 mL copper sulfate solution
- evaporating basin
- gauze mat
- Bunsen burner
- heatproof mat
- tripod
- matches

Method

1. Place the copper sulfate solution into an evaporating basin.
2. Set up the materials as shown in Figure INV5.5A.
3. Put on safety glasses and nitrile gloves if needed. Light the Bunsen burner and turn to the blue flame.
4. In your notebook, record your observations as the water evaporates.
5. Turn off the Bunsen burner before the last few drops evaporate.

Table INV5.5A: Risk assessment

Hazard	Risk (low, medium, high)	Management strategy



▲ **Figure INV5.5A:** For this investigation, set up the materials as shown in this diagram.

Questions

1. Copy the risk assessment table into your notebook.
   a. **Hazards:** Identify three things that could harm the person conducting this investigation.
   b. **Risks:** Decide whether you think there is a low, medium or high chance that each hazard will harm the person conducting this investigation.
   c. **Management strategies:** What steps can you take to make sure each hazard does not harm the person conducting this investigation?
2. A student heated the copper sulfate solution for 30 minutes. Initially, they had 5 mL of the solution. After 10 minutes of heating, there was 3 mL of the solution left. After 20 minutes of heating, 2 mL of the solution remained. Use the information to construct a line graph.
3. Describe the substance before and after evaporation occurred.
4. Compare the initial state and the final state of the mixture. What physical changes did you observe? What happened to the water?

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

AN OPEN FLAME IS A HAZARD. BE CAREFUL. IF YOU BURN YOURSELF, TELL YOUR TEACHER IMMEDIATELY AND PLACE THE BURNT AREA UNDER COLD RUNNING WATER FOR 20 MINUTES.

COPPER SULFATE IS A HAZARD. IF YOU COME INTO CONTACT WITH THE SOLUTION, TELL YOUR TEACHER IMMEDIATELY AND WASH IT OFF YOUR SKIN. ALWAYS WEAR SAFETY GLASSES.

Investigation 5.5B

30 min

Growing crystals

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Processing data

Scientists process the data they collect by identifying and assessing any trends or patterns. These trends can help to explain the relationship between variables.

Hint: *Refer to 'Processing, modelling and analysing' on page 230 of the Science how-to section.*

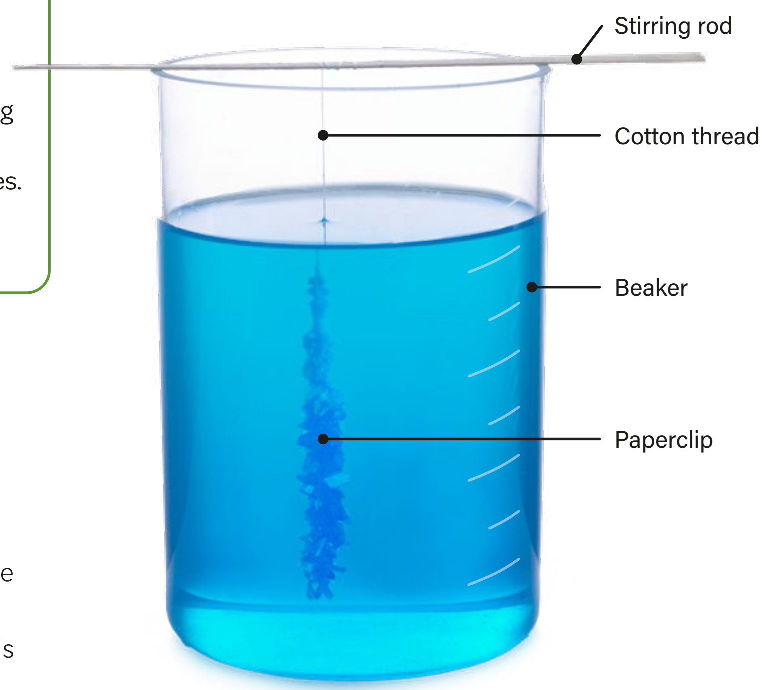


Figure INV5.5B: In this investigation, you will grow crystals inside two beakers.

Aim

To investigate growing crystals from solutions at different temperatures

Materials

For each group:

- safety glasses
- nitrile gloves
- 100 mL measuring cylinder
- cold water from tap
- hot water from tap
- 2 × 100 mL beakers
- 30 g copper sulfate (solid)
- 2 glass stirring rods
- cotton thread
- 2 paperclips
- digital scales

Method

1. Use the measuring cylinder to measure 40 mL of hot water. Pour the water into a beaker.
2. Add 30 g of copper sulfate to the beaker. Stir with a stirring rod until the solid dissolves.
3. Pour half of the volume into another beaker. Cool this beaker by running cold water on the outside until it reaches room temperature.
4. Tie a piece of cotton thread to each stirring rod and attach a paperclip at the other end. Hang the strings with paperclips inside each beaker.
5. Leave the beakers for several days to allow crystals to grow. Measure and record the size of the crystals over time in both beakers.
6. In your notebook, describe what you can see inside each beaker.

Questions

1. Describe the substance before and after crystallisation.
2. Compare the sizes of the crystals in the two beakers. How could you make the crystals bigger?
3. a. Using the information you recorded about the growth in size of the crystals over time, construct an appropriate table.
   b. Using the information from your table, construct an appropriate graph.
   c. Describe the relationship between crystal size, temperature and time of evaporation.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Investigation 5.5C

30 min

Demonstrating distillation

TEACHER DEMONSTRATION

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Constructing graphs

In this investigation, it is important to construct suitable graphs to display the data. These graphs can then be analysed for trends and patterns.

Hint 1: *Refer to 'Processing, modelling and analysing' on page 230 of the Science how-to section.*

Hint 2: *Refer to 'Graphing' on page 270 of the Science how-to section.*

Aim

To investigate separating a salt solution using distillation

Materials

- Bunsen burner
- heatproof mat
- gauze mat
- matches
- tap water
- Liebig condenser
- thermometer
- distillation flask
- retort stand with 2 bossheads and 2 clamps
- receiving flask
- 150 mL beaker containing salt solution
- marble chips

Method

1. Your teacher will set up the materials, as shown in Figure INV5.5C.
2. Your teacher will pour the salt solution into the distillation flask, and then add a few marble chips so that it heats evenly.
3. Your teacher will turn on the water through the condenser, boil the mixture in the flask and collect the water that comes out of the condenser in a receiving flask.

Questions

1. a Identify the components separated as residue and distillate.
   b Identify the equipment used for residue and distillate.
2. Why is it important to use the blue flame when heating materials with a Bunsen burner?
3. Marble chips were added to the solution prior to boiling. Describe the effect they had.
4. Describe the changes of state that happened during the distillation.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

continues ▶

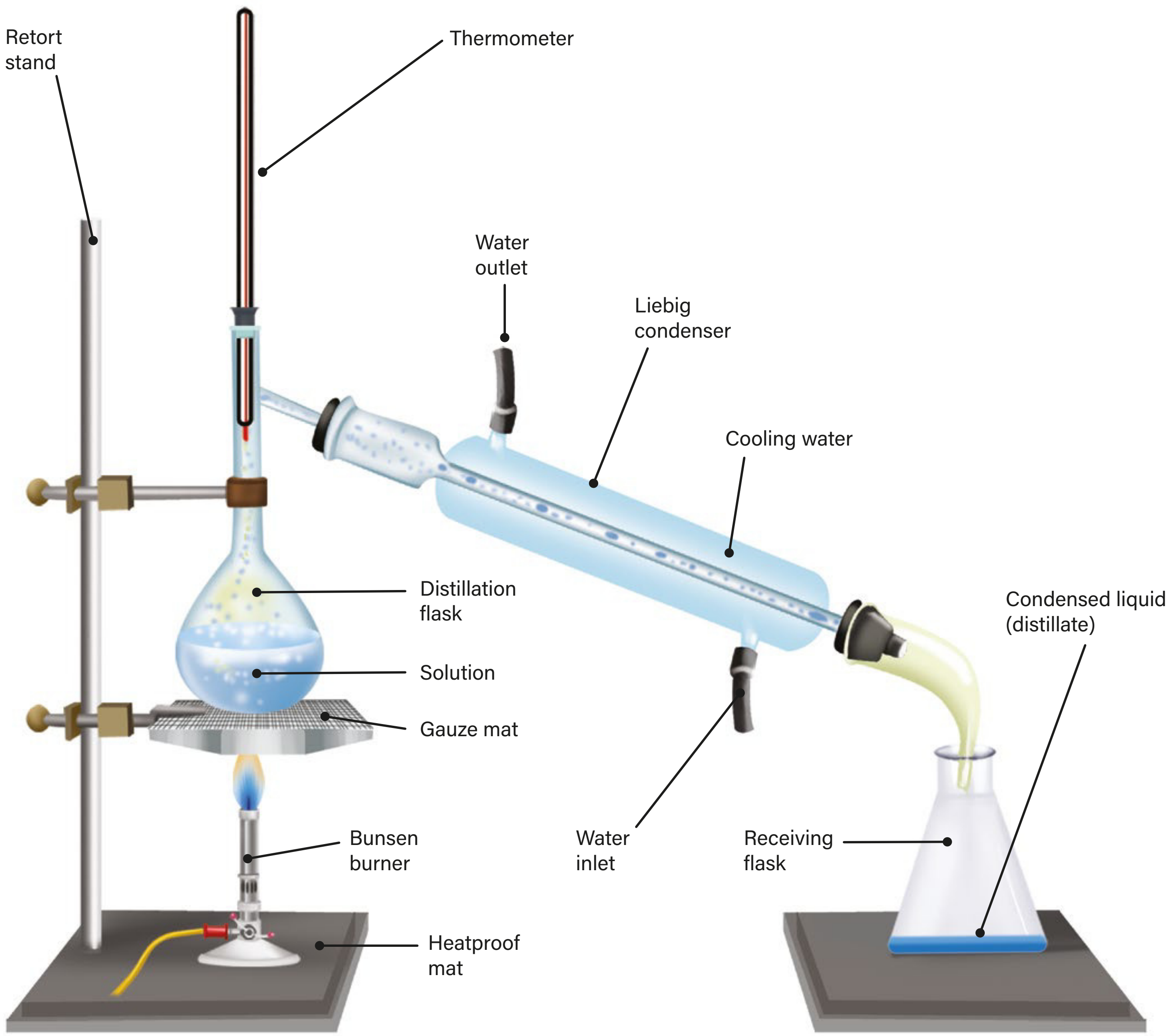


Figure INV5.5C: For this investigation, the equipment will be set up as shown in this diagram.

Investigation 5.6

30 min

Separating colours in dyes by paper chromatography

Inquiry skill: Planning and conducting

Inquiry skill focus: Generating and recording data

The data you collect from a first-hand investigation can be quantitative (numerical information) or qualitative (written descriptions and observations).

Hint 1: *How can you record quantitative data?*

Hint 2: *What observations caused you to record the data in this way?*

Aim

To investigate how chromatography can be used to separate colours

Materials

For each group:

- different coloured confectionery; for example, jelly beans, Skittles, Smarties
- watch glass
- eyedropper (or a couple of plastic pipettes)
- tap water
- filter paper
- 150 mL beaker

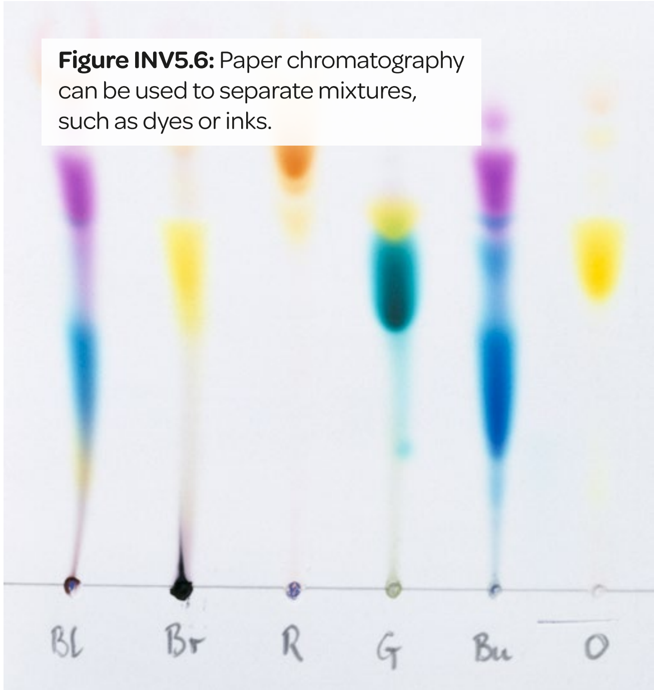


Figure INV5.6: Paper chromatography can be used to separate mixtures, such as dyes or inks.

Method

1. a. Place a sample of the confectionery on a watch glass.
   b. Use the eyedropper to put 2 drops of water on the sample.
2. When the colour in the confectionery starts to dissolve, use the eyedropper to collect some of the coloured liquid.
3. Place 1 drop of the coloured liquid in the middle of the filter paper. Then place the filter paper on an empty beaker.
4. Add 1 drop of water directly over the top of the coloured liquid and observe what happens. Record your observations.
5. Repeat steps 1–4 using a different coloured confectionery.
6. Describe what happens to the sample as the solvent (water) is added.

Questions

1. Describe how you used the filter paper to determine the different colours in each of the dyes.
2. Which confectionery colours are single substances and which ones are mixtures?
3. How many different dyes are needed to make all the confectionery colours?
4. Describe how digital tools, such as a smartphone camera, can be used to improve accuracy in capturing and recording colour patterns.
5. Discuss when this separation technique could be used in the real world to help scientists solve problems.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

NEVER EAT ANYTHING IN A SCIENCE LABORATORY.

Investigation 5.9

30 min

Purifying oily water

TEACHER DEMONSTRATION

Inquiry skill: Evaluating

Inquiry skill focus: Describing types of errors

Investigations in a school laboratory are never perfect. There are often errors in the method or equipment that impact the results and must be identified. Acknowledging and describing these types of errors helps in evaluating the validity of your results and in suggesting improvements for future investigations.

Hint 1: *Identify any variables that are difficult to control, and think of ways to reduce any possible errors.*

Hint 2: *Refer to 'Evaluating' on page 239 of the Science how-to section.*

Aim

To use a separating funnel to separate oil and water

Materials

- 2 × 25 mL measuring cylinders
- 20 mL tap water
- 20 mL oil
- 50 mL separating funnel with stopper
- retort stand with bosshead and clamp
- retort ring
- 2 × 100 mL conical flasks
- tap

Method

1 Your teacher will set up the materials, as shown in Figure INV5.9.

2 Your teacher will measure 20 mL of water and transfer it to the separating funnel.

3 Your teacher will measure 20 mL of oil and transfer it to the separating funnel.

4 Your teacher will stopper the funnel and shake it. Next, they will place the funnel back into the retort ring. Observe the mixture separating and record your observations in your notebook.

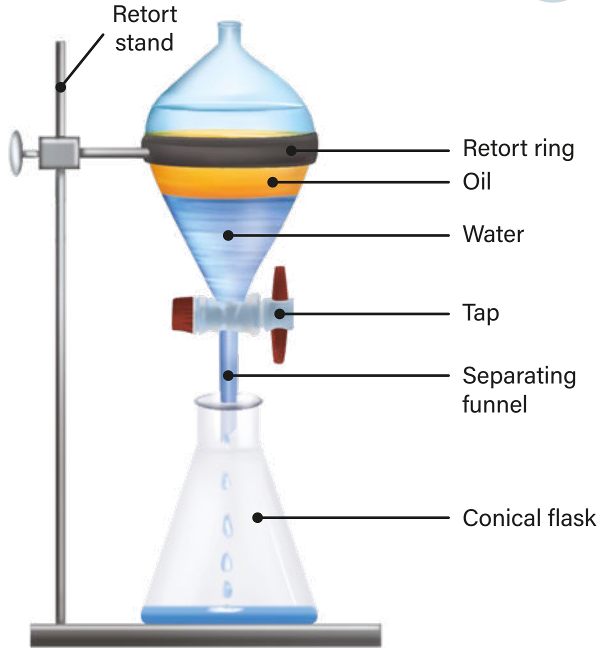


Figure INV5.9: For this investigation, the materials will be set up as shown in this diagram.

5 After two obvious layers have formed, your teacher will slowly open the tap and collect the bottom layer in a flask. Observe the transfer of the contents to a measuring cylinder and measure the volume of the liquid collected.

6 Once your teacher pours out the remaining liquid, measure the volume collected. Record your observations in your notebook.

Questions

1 Describe how the process of the separation was controlled using the tap.

2 Suggest why a separating funnel was used to perform this investigation.

3 Describe what happened to the mixture when the separating funnel was shaken.

4 Explain why the mixture separated after some time.

5 The volumes of oil and water recovered depend on the accuracy of the experiment.

   a Explain how shaking the funnel too hard or not waiting long enough for layers to separate affects the accuracy of the oil and water volumes.

   b Describe how these errors could be minimised.

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Investigation 5.10

60 min

Calculating density

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Processing data

Data can be processed in different ways. One way is by collecting raw measurements and then using mathematical relationships to calculate a new value. This investigation requires you to use the raw data to calculate the density of a variety of objects.

Hint: *Identify the two values required to calculate density.*

Aims

- To determine the volume and mass of regular-shaped and irregular-shaped objects
- To calculate the densities of these objects using the formula $d = \frac{m}{V}$

Materials

For each group:

- 1 cm cube (metal or plastic)
- digital scales
- tap water
- 100 mL plastic measuring cylinder
- marble: 1 cm diameter
- cylinder: 1 cm diameter
- rock: 1 cm diameter
- cork
- eraser: 1 cm diameter
- piece of wood: 1 cm diameter
- paperclip
- nail
- zinc metal (irregular in shape): 1 cm diameter

Method

1 Copy the results table (on the next page) into your notebook, adding a title.

2 Weigh the cube on the digital scales. In the results table, record the mass of the cube in grams.

3 Pour water into the measuring cylinder, up to the 50 mL mark.

4 Place the cube into the measuring cylinder. Be careful not to spill the water.

5 a Does the cube float or sink? Record this information in the results table.

b In the results table, in the 'Final volume' column, record the volume of the water with the cube in it.

6 Work out the volume of the cube using the following formula:

final volume (water + cube) – initial volume (water)

Record the volume of the cube in the results table.

7 Repeat steps 2–6 with the other objects.

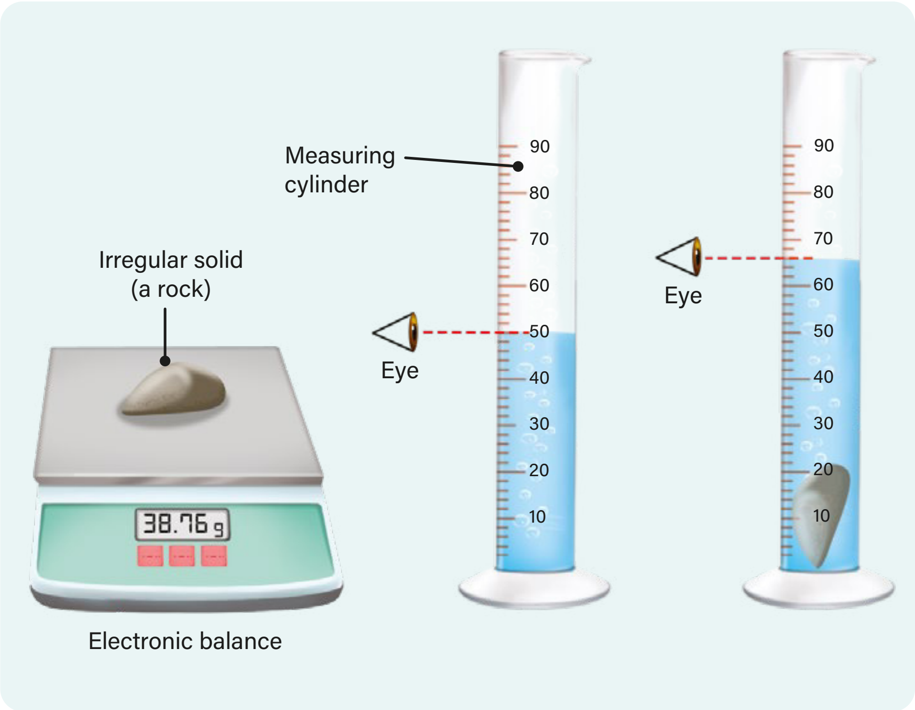


Figure INV5.10: For this investigation, set up the equipment to measure the volume of the objects as shown in this diagram.

continues ▶

Questions

1 Using the density formula ($d = \frac{m}{V}$), calculate the density of each object.
2 For this investigation, identify:
   a the independent variable.
   b the dependent variable.
   c two controlled variables.
3 Propose how you could determine the volume of an object that floats. Identify any errors that could be introduced.
4 Rank the objects from the most dense object to the least dense object.
5 Calculating density is an example of processing data using mathematical relationships. Propose and describe another aspect of this investigation that processes data in a similar way.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Table INV5.10: Results

Object	Mass of object (g)	Float or sink?	Initial volume (mL)	Final volume (mL)	Density from experiment ($d = m/V$) (g/mL)
Cube					
Marble					
Cylinder					
Rock					
Cork					
Eraser					
Piece of wood					
Paperclip					
Nail					
Zinc metal					

Investigation 6.1

30 min

Investigating classroom resources

Inquiry skill: Communicating

Inquiry skill focus: Selecting communication formats

In a scientific report, the information needs to be organised in a way that is easy for the audience to understand. A simple way to effectively organise and display collected data is in a results table.

Answer Question 1 before you start this investigation.

Aim

To investigate the resources that are used in common classroom materials

Materials

For each group:

- selection of classroom items (e.g. paper, ruler, eraser, pencil case, calculator, desk, chair, flooring)

Figure INV6.1: Common classroom items are made from both renewable and non-renewable resources.

Method

1. Select up to 10 items in the classroom and add them to the table you constructed in Question 1.
2. Identify the materials each item is made from. You may need to do some research.
3. Identify how the main material in each item is obtained.
4. Determine whether the item is made from renewable or non-renewable resources.
5. Compare your list with those of others in your class.

Questions

1. Construct a results table in your notebook to record the data you will collect in this investigation.

   Hint 1: *Read the materials and method to work out what data you will be collecting.*

   Hint 2: *List each of the different materials in the rows of the table.*

   Hint 3: *List the factors you are investigating in the columns of the table.*
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 results show that: *(respond to the aim)*.'

Investigation 6.2

30 min

Making bioplastic

Inquiry skill: Planning and conducting
Inquiry skill focus: Describing ways to minimise risk
Brainstorm with a partner to identify at least three hazards or risks in this investigation. Write down the actions you will take to minimise each of them.

Aim

To investigate how plastic is made, using cornflour

Materials

For each group:

- hotplate
- 250 mL beaker
- tablespoon
- teaspoon
- cornflour
- vinegar
- vegetable glycerine
- tap 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 INV6.2: 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.

60 min

Investigating soil erosion

Inquiry skill: Evaluating

Inquiry skill focus: Supporting findings with evidence

The results we obtain in an investigation should always be explained using scientific knowledge in the discussion of a scientific report. (See the Science how-to section, page 250.)

Hint 1: *Think about the scientific concepts that are important for the investigation.*

Hint 2: *Summarise the data and any trends shown in your results.*

Hint 3: *Explain the data and trends using scientific understanding. For example, 'The results showed that ... This is because ...'*

Aim

To investigate factors that influence soil erosion

Materials

For each group:

- 6 empty soft-drink bottles (equal shape and size)
- scissors
- glue or plasticine
- piece of board or bench space (30 cm × 30 cm)
- soil
- seedlings
- mulch
- string
- 250 mL beaker
- tap water

Method

1. Cut a rectangle (approximately 10 cm × 20 cm) out of one side of three of the bottles.
2. Using glue or plasticine, position the bottles on their sides (holes facing up) on a table or board so that they will not move. The necks of the bottles should stick out over the edge.
3. Add an equal amount of soil to each of the three bottles.
4. Plant your seedlings in the first bottle.
5. Cover the soil in the second bottle with a layer of mulch.
6. Leave the soil uncovered in the third bottle.
7. Cut the other three bottles in half and carefully pierce a hole on either side to thread the string through so that it can be suspended underneath the necks of the three bottles.
8. Use the beaker to measure 250 mL of water and carefully pour the water into each bottle containing soil, pouring into the bottom of the bottle, away from the neck.
9. When the water has drained through, record your observations of the differences in the water that collects in the buckets underneath the neck.
10. Repeat the watering process over several days, continuing to record your observations.

Questions

1. Compare the colour of the water in each of the collecting cups.
2. Describe the level of soil remaining in each of the three bottles.
3. Suggest why the colours and levels of soil are different.
4. Farmers will often leave the roots of their old crop in the ground until they are ready to plant their new one. Justify why this is a useful strategy for preserving soil resources.
5. A farmer observed that soil will erode more from paddocks that are on a slope than in paddocks on flat ground. Design an experiment to test how the angle of a slope affects the amount of soil eroded.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

BE CAREFUL USING THE SCISSORS TO CUT INTO THE BOTTLE. IF YOU CUT YOURSELF, TELL YOUR TEACHER IMMEDIATELY.

Investigation 6.4

60 min

Designing a windmill to lift a weight

Inquiry skill: Communicating

Inquiry skill focus: Using digital technologies to organise and present findings

Digital technologies allow us to present scientific findings in different ways. They can be used to construct tables and graphs, and to record images and videos.

Think about how you could use digital technologies to organise and present your findings for this investigation.

Hint: Think about the observations you will be making and the results you will be gathering.

Aim

To investigate which design for a windmill can lift the heaviest weight

Materials

For each group:

- cotton reel
- piece of dowel to fit through cotton reel
- tape
- string
- block of polystyrene
- paper cup
- retort stand with bosshead and clamp
- light cardboard, heavy cardboard, plywood and other materials suitable to make turbine blades
- skewers
- selection of fishing line sinkers or other small weights
- fan

Method

1 Design a table with appropriate columns and rows to record your data and observations.
2 Insert the dowel through the cotton reel and secure it with tape so that the reel will not spin. This will be how you attach the string that will lift the weight.
3 Insert the other end of the dowel into the polystyrene block. This will be where you insert your turbine blades.
4 Carefully clamp the dowel into the retort stand and clamp. The dowel must still be able to spin freely.
5 Tape one end of the string onto the cotton reel. Thread the other end through the cup.
6 Determine the size, shape and number of blades that your windmill will have. Construct these out of your chosen material.
7 Consider the angle (pitch) that your blades will have compared to the front of the windmill.
8 Assemble your windmill from all of your components.
9 Place different weights in the cup. Use the fan to try to turn the windmill blades and lift each weight.
10 Record your observations and the heaviest weight your design could lift. Compare your findings with those of your classmates.

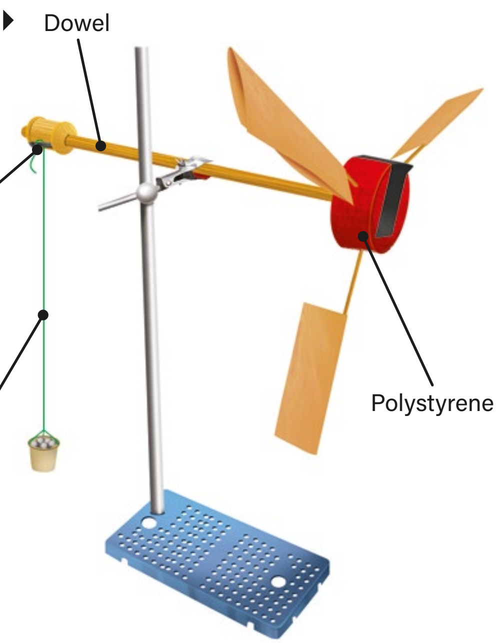
Questions

1 Which design was able to lift the heaviest weight?
2 Why is the angle of the windmill blades so important?
3 What materials (not provided) do you think would make an even stronger windmill?

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Figure INV6.4: ▶ Set up your materials as shown in this diagram.



Investigation 6.5

45 min

Mining for chocolate chips

Inquiry skill: Evaluating

Inquiry skill focus: Describing types of errors

An error is something that will cause you to record a value or observation that is higher or lower than in reality. Errors can be caused by faulty equipment, an experimental flaw, changing environmental conditions, or many other things. It is important to be able to describe errors so that we can identify how they may impact scientific results.

Hint 1: *Review the Science how-to on page 239.*

Hint 2: *Carefully read through the materials and method for the investigation. Are there any areas where an error could be present?*

Hint 3: *Classify the errors you have identified as either random or systematic and describe how they may impact your results.*

Aim

To investigate which brand of chocolate chip biscuit contains the highest percentage of 'metal' in the 'ore'

Materials

For each group:

- chocolate chip biscuits (each group or pair to have one each of several different brands)
- cupcake liner
- electronic balance
- toothpick

Method

Mining for metal in ore

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Place your biscuit in a cupcake liner. Set to zero mass on the electronic balance. Weigh and record the mass of the biscuit, then remove it and any crumbs from the liner.
3. Using the toothpick, carefully remove the chocolate chips from the biscuit, keeping them separate from those of other biscuits.
4. Place the chocolate chips in the cupcake liner. Set to zero mass on the balance. Weigh and record the mass.
5. Calculate the percentage of chocolate chips in the biscuit compared to the 'waste'.
6. Share your results with the rest of the class and calculate an average for all brands of biscuit.

Questions

1. Which brand contained the highest percentage of chocolate chips?
2. Which brand contained the lowest percentage of chocolate chips?
3. Compare your results with other groups. How were they similar? How did they differ?
4. Compare the class average results to the labelled percentage of chocolate chips – how did they differ?
5. What 'mining' strategies did you use? Could you have easily rehabilitated the biscuits after the chocolate chips were removed? How could you have changed your strategies so they were more 'environmentally friendly'? How do you think this could impact any profits?

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Table INV6.5: Results

Biscuit brand	Total biscuit mass (g)	Mass of chocolate chips (g)	% by mass of chocolate chips	Class average % by mass of chocolate chips	Labelled % of chocolate chips

Investigation 7.1

30 min

Modelling day and night

Inquiry skill: Questioning and predicting

Inquiry skill focus: Developing a hypothesis

Part of a scientific investigation includes proposing a hypothesis, which is a suggested explanation or prediction of a scientific problem that can be tested with an investigation.

Write your hypothesis in your notebook using the format below.

If ... then ... because ...

Hint 1: What do you know about the relationship between the position of Earth and the Sun?

Hint 2: What do you know about the rotation of Earth on its axis?

Aim

To investigate, using a model, how day and night are explained by the relative positions of the Sun and Earth

Materials

For each group:

- globe of Earth
- torch

Method

1. Have one person hold the torch. This represents the Sun.
2. Have another person in charge of the globe. This represents Earth. (The globe will have the correct tilt.)
3. Dim the light and aim the torch at the globe. Note that half of the globe is lit and half is in darkness.
4. Rotate the globe anticlockwise and observe how the light travels over the continents.

Questions

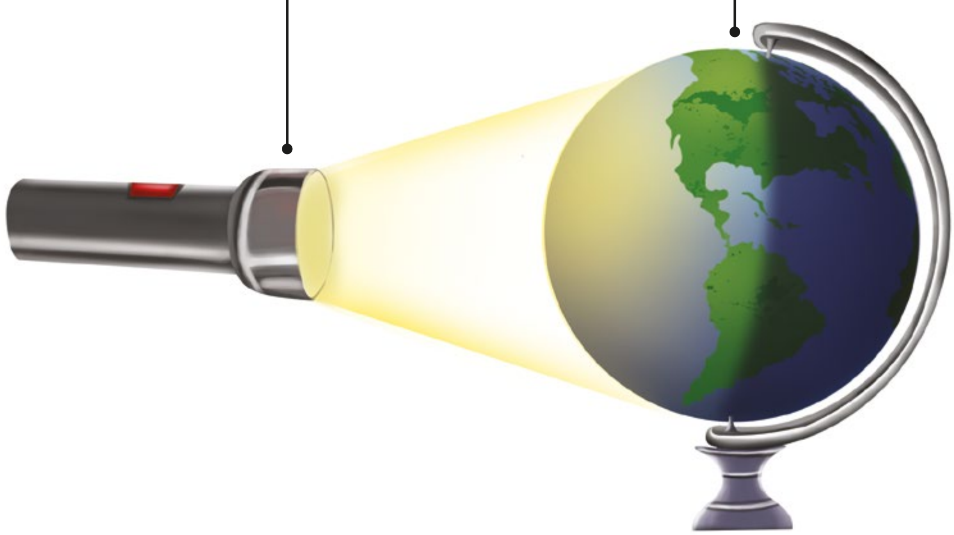
1. Propose how much of Earth is in daylight at any time.
2. Propose how much of Earth is in darkness at any time.
3. When it is day in Australia, propose a continent that has night.
4. Explain whether it is possible for New York and New Zealand to both have daylight at the same time.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Figure INV7.1: The Sun and Earth system can be modelled using a torch and a globe.



Investigation 7.3

30 min

Modelling the seasons

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Constructing graphs

Graphing data shows the visual relationship between the independent (changed) variable and the dependent (measured) variable.

Hint 1: *What type of graph should be used for the data gathered in this investigation?*

Hint 2: *How can you ensure your data goes onto the correct graph axis? See page 232 of the Science how-to section for more help with graphing.*

Aim

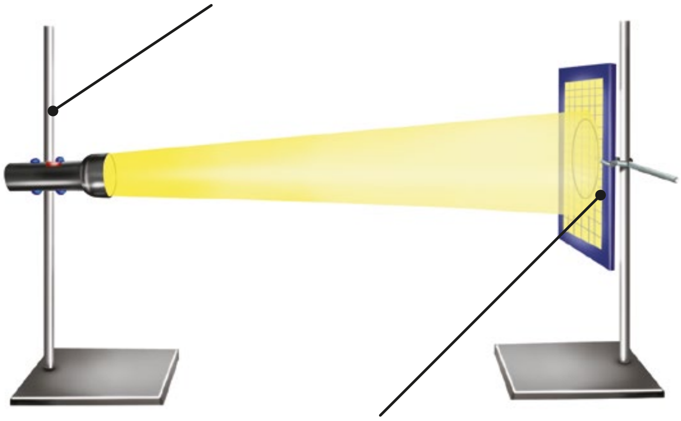
To investigate, using a model, how Earth's tilt affects how the Sun's rays strike Earth and cause seasons

Materials

For each group:

- backing board
- clips
- 7 sheets of graph paper
- 2 retort stands with bossheads and clamps
- torch
- ruler
- pencil
- protractor

Figure INV7.3: Set up the apparatus to allow the torch to light up a circle on the graph paper.



Method

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Set up the apparatus as shown.
3. Dim the lights so that the torch makes a clear circle on the graph paper.
4. Check that the board is parallel to the retort stand.
5. Measure and record the distance between the torch and the graph paper. This distance should be kept constant for each test.
6. Use a pencil to trace the lit area. Be careful not to move the graph paper.
7. Remove the graph paper and label it 0°.
8. Place another sheet of graph paper on the board and tilt the board by 10° so that the top of the board is further away from the torch. Trace the lit area. Label this sheet with the angle of the board.
9. Repeat step 8 for each angle up to 60°.
10. Count the number of squares inside the traced areas and record them in the results table.

Questions

1. Graph your results, with the angle in degrees on the horizontal axis and the area in squares on the vertical axis. Remember to choose an appropriate scale.
2. Suggest which angle represents places near the equator. Justify your response.
3. Suggest which angle represents Antarctica. Justify your response.

Conclusion

Copy and complete:
'The results show that: (*respond to the aim*).'

Table INV7.3: Results

Angle (°)	Area (number of lit squares)

Investigation 7.4

Modelling eclipses

Inquiry skill: Evaluating

Inquiry skill focus: Supporting findings with evidence

The results we obtain in an investigation should always be explained using scientific knowledge in the discussion of a scientific report.
(See the Science how-to section on page 250.)

Hint 1: *Think about the scientific concepts that are important for the investigation.*

Hint 2: *Summarise the data and any trends shown in your results.*

Hint 3: *Explain the data and trends using scientific understanding. For example, 'The results showed that … This is because …'*

Aim

To investigate, using a model, how solar and lunar eclipses are explained by the relative positions of the Sun, Moon and Earth

Materials

For each group:

- cardboard tube or roll of paper
- scissors
- sticky tape
- square of heavy card
- polystyrene ball
- coathanger wire (length: 20 cm)
- ping-pong ball (or small polystyrene ball)
- aluminium foil
- retort stand with bosshead and clamp
- torch

Method

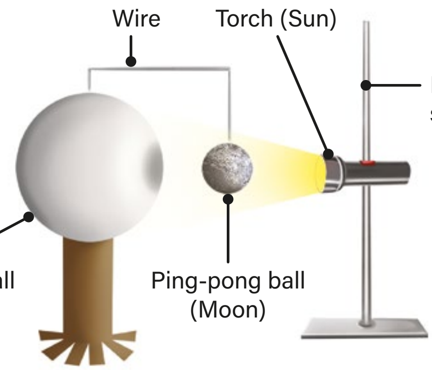
1. Make a series of small (2 cm), even, vertical cuts around each end of the cardboard tube.
2. Bend the cut pieces of both ends of the cardboard tube outwards and stand the tube upright. Tape one end of the tube to one of the pieces of heavy card to create a base for the model.
3. Tape the base to the polystyrene ball. This is the model of Earth.
4. Insert one end of the wire vertically into the Earth model.
5. Make two small holes in the ping-pong ball for the wire to pass through.
6. Cover the ping-pong ball with aluminium foil. This is the model of the Moon.
7. Bend the wire to secure the Moon. The Moon's equator should be level with Earth's equator.
8. Adjust the torch using the retort stand so that it is in line with Earth's equator.
9. Dim the lights in the classroom.
10. Follow the instructions on the next page to model a solar eclipse and a lunar eclipse.

30 min

To model a solar eclipse (see Figure INV7.4a):

1 Stand facing the torch and swing the wire around until the Moon casts a shadow on Earth. The Moon is now positioned between Earth and the Sun. The Moon is blocking the Sun's light and preventing the light reaching Earth.
2 Show that the shadow moves by slowly rotating the wire.
3 Bend the wire up so that the Moon only partially blocks the Sun.

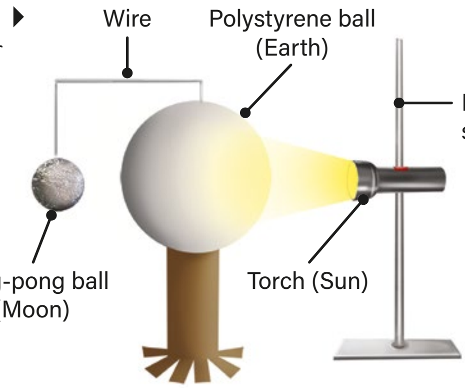
Figure INV7.4a: To model a solar eclipse, set up the materials as shown.



To model a lunar eclipse (see Figure INV7.4b):

1 Stand facing the torch and swing the wire around until the Moon is completely behind Earth. Earth is now positioned between the Moon and the Sun. Earth is blocking the Sun's light and preventing the light reaching the Moon.
2 Bend the wire so that only part of Earth's shadow falls on the Moon, to model a partial lunar eclipse.

Figure INV7.4b: To model a lunar eclipse, set up the materials as shown.



Questions

1 Use your observations from the investigation to identify the object that:
   a is in shadow during a solar eclipse.
   b casts the shadow during a solar eclipse.
   c is in shadow during a lunar eclipse.
   d casts the shadow during a lunar eclipse.
2 Use your scientific understanding of eclipses to write a short paragraph that explains your observations of the relative positions of Earth, the Moon and the Sun during solar and lunar eclipses that you identified in Question 1.
3 Use your observations from the investigation to identify the phase of the Moon during a:
   a solar eclipse.
   b lunar eclipse.
4 Use your scientific understanding of eclipses and Moon phases to write a short paragraph that explains your observations of the phases of the Moon during solar and lunar eclipses that you identified in Question 3.
5 Use your scientific understanding to discuss if a solar eclipse can be observed all around the world.
6 Use your scientific understanding to discuss if a lunar eclipse can be observed all around the world.
7 Propose what you would observe during a solar eclipse if you were standing on the Moon looking at Earth.
8 Undertake research to find out if Mars experiences solar and lunar eclipses. Write a short paragraph that explains what you would observe if you lived on Mars. You may like to include a diagram.

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Modelling the Moon's phases

Inquiry skill: Questioning and predicting

Inquiry skill focus: Constructing scientific questions

Turn the aim of this investigation into a question that asks what you are trying to discover. This should be a question that can be investigated scientifically.

Hint 1: *Your investigation question can also be used as a title for a scientific report.*

Hint 2: *Make sure that your investigation question has a question mark at the end.*

Aim

To investigate, using a model, how the Moon's phases are explained by the relative positions of the Sun, Moon and Earth

Materials

For each group:

- ping-pong ball or small polystyrene ball
- 10 cm length of wire
- torch
- retort stand with bosshead and clamp
- globe or polystyrene ball

Figure INV7.5a:
Set up the materials as shown, with the 'Moon' between the torch and 'Earth'

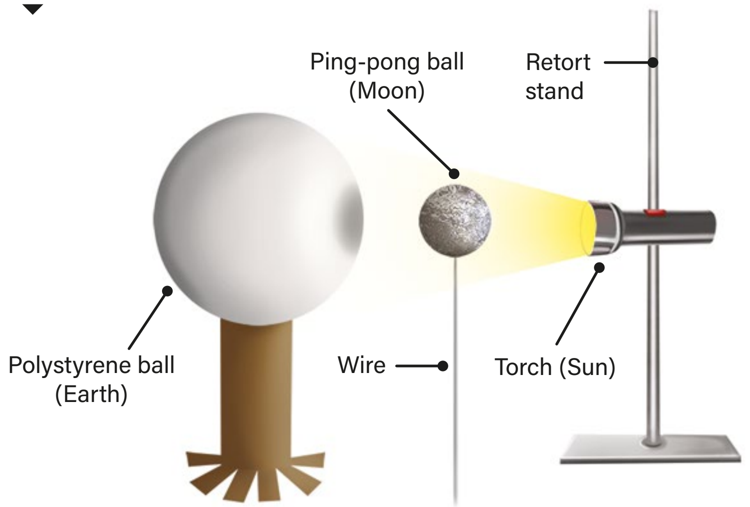
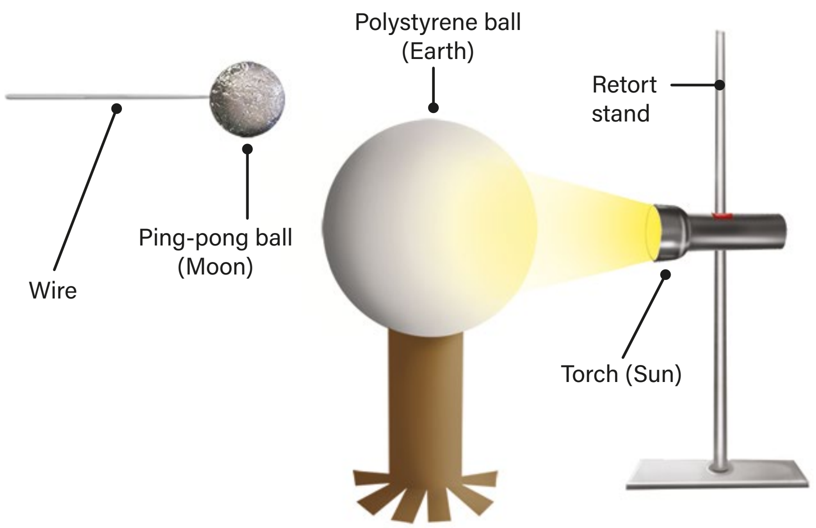


Figure INV7.5b:
Move your 'Moon' to the opposite side of the globe, so it is fully lit by the torch.



30 min

Method

1 Complete Questions 1 and 2.
2 Copy and complete the results table into your notebook, adding a title and rows as needed.
3 Pierce the ping-pong ball with the length of wire. This will allow you to hold your model of the Moon.
4 Clamp the torch to the retort stand. This will model the Sun.
5 Place your globe about 30 cm away from the torch and retort stand.
6 Holding the wire, place the ping-pong ball between the globe and Earth (Figure INV7.5a). You should observe that the side of the ping-pong ball facing the torch is lit up, while the side facing the globe is in darkness. This represents a new Moon.
7 Now, place the ping-pong ball on the opposite side of the globe from the torch (Figure INV7.5b). You should notice that now the side of the ping-pong ball that is facing the globe is lit up (unless it is directly behind the globe). This represents a full Moon.
8 Slowly move the ping-pong ball to revolve around Earth. You should notice that half of it is always lit by the torch, but from Earth you can observe different phases. Use Figure 7.15 in Section 7.5 to help you model the different phases.
9 Use your observations to complete the results table for each of the eight moon phases.

Table INV7.5: Results

Moon phase	Relative position of Earth, the Moon and the Sun	Diagram of Moon phase observed from Earth

Questions

1 Construct a scientific question that can be answered by completing this investigation.
2 Construct a hypothesis that addresses the scientific question.
3 Identify the phase of the Moon during a solar eclipse. Use your apparatus to check your response.
4 Identify the phase of the Moon during a lunar eclipse. Use your apparatus to check your response.
5 Analyse your results to determine if your hypothesis was correct.
6 Conduct research to find out how the hemisphere you are in affects how the Moon appears. Write a paragraph summary and include diagrams to assist your explanation.

Conclusion

Copy and complete:
'The results show that: (*respond to the aim*).'

Investigation 7.8

30 min

Making a simple telescope

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Analysing scientific models

Analysing a scientific model is useful in determining its effectiveness in modelling what is happening in the real world.

Hint 1: *Think about what the model is trying to replicate.*

Hint 2: *What does the model replicate well? What are its weaknesses?*

Hint 3: *Can you suggest ways to improve the model?*

Aim

To investigate how telescopes use lenses to magnify distant objects

Materials

For each group:

- weak convex lens (+2.5D) or lens from reading glasses
- metre ruler
- Blu-Tack or plasticine
- retort stand
- lamp
- greaseproof paper
- strong convex lens (+14D) or magnifying glass

Method

1. Attach the weak lens to one end of the metre ruler with plasticine or Blu-Tack.
2. Set the metre ruler into the retort stand to hold it steady, with the weak lens pointing away from you.
3. Put the lamp on a table at the other end of the room and turn it on.
4. Turn the retort stand until the metre ruler is aimed at the lamp.
5. Hold a piece of greaseproof paper just above the metre ruler. Move it along the ruler until you see a small image of the lamp on the paper. Have a partner hold it at that position.
6. Hold the strong lens at the other end of the metre ruler. Using one eye, look through the lens at the image on the paper. Move the lens until the lamp image is magnified.
7. Have your partner take the paper away, but continue looking through the strong lens. You should still see the image of the lamp, although it will be brighter than before.

Questions

1. Propose why this telescope requires two lenses, rather than just one.
2. Propose why the image is brighter once the paper is taken away.
3. Explain how this simple telescope is different from a proper telescope.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

30 min

Creating a scale model of the solar system

Inquiry skill: Evaluating

Inquiry skill focus: Identifying investigation errors and assumptions

An error is something that will cause you to record a value or observation that is higher or lower than in reality. Errors can be caused by numerous things, such as faulty equipment, an experimental flaw or changing environmental conditions. When conducting a scientific investigation, we aim to minimise errors and to be able to identify them and to understand how they may impact the results.

Hint 1: *Creating a scale is an example of a ratio. See 'Understanding ratios' in the Science how-to section on page 263.*

Hint 2: *Carefully read through the materials and method for the investigation. Are there any areas where an error could be present?*

Hint 3: *When you have identified a source of error, think about how you could minimise or control it. Could you use different equipment or ensure that you use a specific technique?*

Aim

To construct scale models of the solar system

Figure INV7.9a: Modelling the solar system

Part 1

MODELLING THE DISTANCE BETWEEN PLANETS

Materials

For each group:

- A space to create your scale model (e.g. school quad, oval, classroom wall, butchers paper)
- Something to measure your space (e.g. ruler, tape measure, trundle wheel)
- Something to mark out your scale (e.g. chalk, markers or witches hats)

Method

1. Copy the results table for Part 1 (Table INV7.9b) into your notebook.
2. Determine where you will create your scale model.
3. Measure the length that your model will be. The start will represent the Sun and the end will represent the outer reaches of the solar system.
4. Determine the best scale to use from Table INV7.9a, or calculate your own.

Table INV7.9a: Suggested scales depending on length of space available

Length of space (m)	Scale
1	1 AU = 2 cm
10	1 AU = 20 cm
50	1 AU = 1 m
100	1 AU = 2 m

5. Use the scale and the distance from the Sun in Table INV7.9b to calculate the distance each planet will be from the Sun.
   Hint: Multiply the distance in AU by the scale distance in cm or m.
6. Use your measuring device and markers to create your scale model in your chosen space. Mark out the start of your scale as the 'Sun' and clearly label where each planet would be.

continues ▶

Table INV7.9b: Results Part 1: Modelling the distance between planets

Planet	Distance from Sun (AU)	Distance in scale (AU × ______)
Mercury	0.39	
Venus	0.72	
Earth	1	
Mars	1.52	
Jupiter	5.2	
Saturn	9.54	
Uranus	19.2	
Neptune	30.06	

Questions

1. Describe one technique you used to ensure your measurements were precise when creating your scale of the solar system.
2. Describe what you noticed about the distance between the Sun and the inner (rocky) planets of the solar system.
3. Describe what you noticed about the distance between the Sun and the outer (gassy) planets of the solar system.
4. Evaluate the scale you used to create your model. Consider what made it easy to use and what made it difficult to use. Is there a way that you think would make it easier to show the distances between the planets in the solar system?
5. Proxima Centauri is the closest star to the Sun. It is 268 550 AU (4.2465 light years) away. Use your scale to calculate where you would need to place Proxima Centauri on your scale model.
6. Undertake some research to find the distances that other objects are in the solar system compared to the Sun – for example, the asteroid belt, dwarf planets, spacecraft. Add these to your scale model.

Part 2

MODELLING THE SIZE OF THE SUN AND PLANETS

Materials

For each group:

- butchers paper
- pencil, pen or marker
- ruler or tape measure
- drafting compass
- string

Method

7. Copy the results table for Part 2 (Table INV7.9c) into your notebook.
8. Think about the space you have available to create your scale model. This could be by overlapping all circles on one large sheet of paper, or by creating individual circles that are cut out.
9. Determine the diameter that you will use for Earth. Write this in the results table.
10. Complete the results table by multiplying the value of the 'Size compared to Earth' by the diameter you have chosen for Earth.

    For example, to determine the diameter of the Sun if Earth is 5 cm:

    109 × 5 = 545 cm
11. Calculate the radius to scale by dividing the diameter to scale by 2.

    For example: 545 / 2 = 272.5 cm
12. Use the drafting compass and the ruler to draw circles representing each object in the solar system. *Hint:* For the larger radii, tie the pencil to a piece of string that is the same length as the radius of the object and use it like a drafting compass to create the circle (Figure INV7.9b).

Figure INV7.9b: Use a pencil tied to a length of string (like a drafting compass) to create a circle.

Questions

7 Describe one technique you used to ensure your measurements were precise when creating your scale model of the Sun and planets.

8 Describe what you noticed about the different sizes of the planets in the solar system.

9 Describe what you noticed about the size of the Sun compared to the different planets in the solar system.

10 Proxima Centauri is the closest star to our Sun and is about 16 times the diameter of Earth.

   a Calculate how large it would be on your scale model.

   b Compare the size of Proxima Centauri to the Sun, Earth and Jupiter.

11 Discuss if you could combine the scale models you created in Parts 1 and 2, or if you would need to make changes. Justify your response.

Table INV7.9c: Results Part 2: Modelling the size of the Sun and planets

Object	Size compared to Earth (diameter)	Diameter to scale (units of measurement)	Radius to scale (units of measurement)
Sun	109		
Mercury	0.4		
Venus	0.9		
Earth	1.0		
Mars	0.5		
Jupiter	11.2		
Saturn	9.5		
Uranus	4.0		
Neptune	3.9		

Investigation 8.1

30 min

Push, pull or twist

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Organising data

Before you start your investigation, design a table with appropriate columns and rows to record your data and observations.

Hint 1: *Use a ruler to draw your table so that it is neat, clear and easy to read.*

Hint 2: *Each item on the materials list should be listed down the left-hand column of your table; one row per item.*

Hint 3: *Refer to 'Processing, modelling and analysing' on page 230 in the Science how-to section to help you determine what headings to use for the other columns.*

Aim

To investigate the effects of forces on different objects

Materials

For each group:

- elastic band
- tennis ball
- plasticine or Blu-Tack
- plastic ruler
- metal ruler
- A4 piece of paper

Figure INV8.1

Method

1. Stretch the elastic band as far as it will go, then slowly let it go back to its normal shape.
2. Drop the tennis ball so that it bounces off the floor, then catch it before it falls again.
3. Squash the plasticine or Blu-Tack into at least three different shapes.
4. Hold one end of the plastic ruler in each hand. Bend the ruler so that it flexes, then let it go back to its normal shape.
5. Repeat step 4 for the metal ruler, if possible.
6. Hold one corner of the paper in each hand. Bring your hands together so that the paper scrunches, then pull them apart until it tears.
7. For each object, record whether the forces you applied acted as a push, pull or twist. Consider all of the different forces that you applied to each object. Record your observations of what else happened when you applied forces.

Questions

1. Were there any situations where you applied more than one force to an object? Describe the effect of applying multiple forces.
2. Identify which objects changed their shape when you applied a force. Was this change temporary or permanent?
3. Did applying force affect the movement of any objects? If so, explain why.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Investigation 8.2

30 min

Balloon rockets

Inquiry skill: Questioning and predicting

Inquiry skill focus: Making predictions

What do you think makes a balloon travel?

To investigate this, you need to identify all the variables involved. Maybe it is the type of string or straw, or how much air starts in the balloon. In any event, a key component of first-hand investigations is making a prediction of the outcome of the investigation. Before you begin, predict which variable will have the biggest impact on how far the balloon will travel.

Hint: Base your predictions on what you already know or have observed.

Aim

To investigate which variables make a balloon rocket travel furthest

Materials

For each group:

- masking tape
- balloons
- string
- paper straw
- scissors

Method

1 Construct a results table in your notebook to record the data you will collect in this investigation. (*Hint:* Read the materials and method to determine what data you will be collecting. List the independent variables in the left column.)

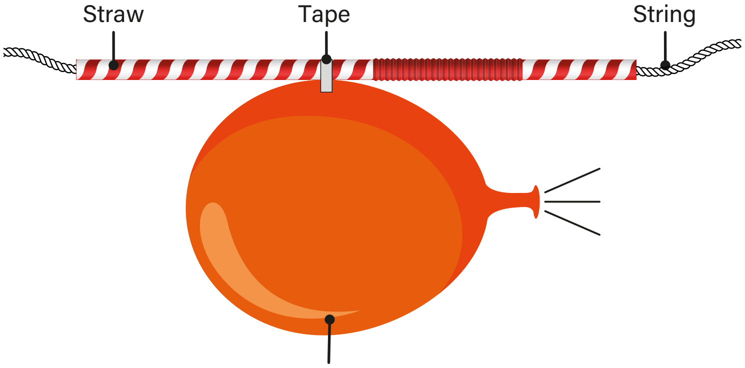


Figure INV8.2: For this investigation, set up the materials as shown in this diagram.

2 Using a piece of masking tape, stick a straw to the balloon.

3 Use the scissors to cut a piece of string and then thread it through the straw.

4 Inflate the balloon and hold it closed.

5 Release the balloon so that it travels along the string. Record the distance the balloon travels in your results table.

6 Write a list of all the variables involved in making the balloon travel along the string.

7 a Choose one variable to change (an independent variable). Keep the other variables the same (the controlled variables).

b Predict if the balloon will travel further than in the original test.

8 Repeat steps 2–5.

9 Record the results in your results table. Repeat the test for as many variables as you can think of.

Questions

1 Identify the different forces involved with your balloon rocket:

a Which are direct forces?

b Which are indirect forces?

2 Explain the effect each of the forces has on the movement of the balloon. Construct a force diagram to support your response.

3 Construct a graph to present your data visually.

4 Describe how your results compare with your predictions. Explain why they were the same or different, with reference to the characteristics of forces and mass.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

DO NOT SHARE THE BALLOON BETWEEN REPETITIONS. EACH STUDENT MUST HAVE THEIR OWN BALLOON.

Investigation 8.3

30 min

Blowball

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Identifying and discussing trends in data

Write your observations (qualitative data) for each aspect of the investigation. Using the information gathered, you can identify, describe and explain the relationships found.

Aim

To investigate the effects of unbalanced forces on a ping-pong ball

Materials

For each group:

- 4 paper straws
- table
- ping-pong ball

Method

1 Gather into groups of four. Each member of the group takes one straw and stands at a different side of the table.

2 Place the ping-pong ball in the centre of the table.

3 Take turns to blow through your straws to move the ball around the table.

4 Have one group member blow the ball across the table while the others blow on it in the opposite direction.

5 Have another group member blow the ball across the table while the others blow on it from the sides.

6 Divide into two pairs, with each pair on a different side of the table. As a pair, try to blow the ball across the table and off the side while the other pair does the same.

7 Record your observations (qualitative data) in your notebook. In particular, describe how different-sized forces affected the motion of the ping-pong ball.

DO NOT SHARE STRAWS. EACH STUDENT MUST HAVE THEIR OWN STRAW.

Questions

1 Identify when the forces on the ball were balanced. Describe each instance.

2 Describe what happened to the speed and direction of the ball when you blew on it as it moved towards you.

3 Explain, with reference to forces, what happened when you blew on the ball as it moved at a right angle to you.

4 Construct a force diagram showing the forces that were acting on the ball as you blew it away from you.

5 Review the observations you wrote in your notebook. Describe and explain any trends or relationships observed in the data.

Conclusion

Copy and complete:
'The results show that: (*respond to the aim*).'

Figure INV8.3: In this investigation, you move objects by blowing air through a straw.

Investigation 8.4

20 min

Heat from friction

Inquiry skill: Evaluating

Inquiry skill focus: Identifying investigation errors and assumptions

Investigations in a school laboratory are never perfect. There are usually assumptions that are made, and unavoidable errors in the method that impact the results and must be acknowledged. What assumptions and errors are present in this investigation?

Hint 1: *Are we assuming that all materials should be the same temperature?*

Hint 2: *Does it make a difference if you rub it 20 or 30 times?*

Hint 3: *Refer to step 1 of 'Evaluating' in the Science how-to on page 239.*

Aim

To investigate the connection between friction and heat

Materials

For each group:

- microfibre cloth
- wire coathanger
- wooden skewer
- plastic rod
- cardboard roll

Method

1. Pick up each item to see how warm or cool it is.
2. Firmly rub the plastic rod 20–30 times with the cloth. Carefully feel it and record how its temperature has changed.
3. Repeat step 2 with each of the other items.
4. Record any other observations you make.

Questions

1. Identify which item had the greatest change in temperature.
2. Identify which item had the least change in temperature.
3. Explain how friction caused the change in temperature.
4. Discuss how the assumptions and errors may have impacted the results. Provide examples that reference your results.

Conclusion

Copy and complete:
'The results show that: (*respond to the aim*).'

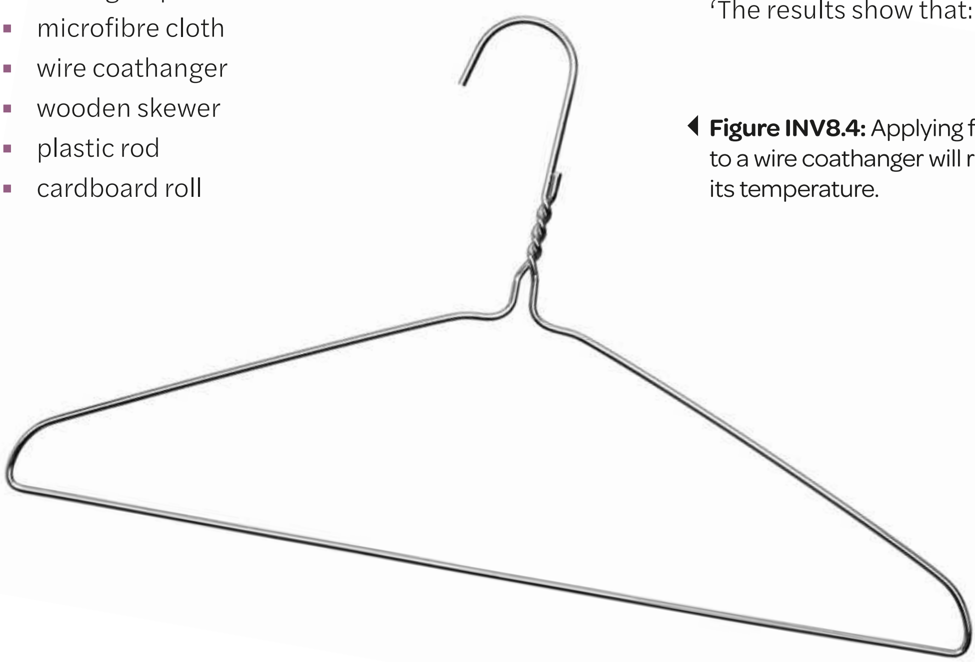


Figure INV8.4: Applying friction to a wire coathanger will raise its temperature.

Investigation 8.5

30 min

Friction of materials

Inquiry skill: Questioning and predicting

Inquiry skill focus: Developing a hypothesis

Before you develop a hypothesis, identify your independent, dependent and controlled variables. The independent variable is the one thing that 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. Then, you can use an 'If ..., then ...' statement to develop your hypothesis.

Hint 1: *Structure your hypothesis like this: 'If (something to do with your independent variable), then (something to do with your dependent variable).'*

Hint 2: *Refer to step 4 of 'Questioning and predicting' in the Science how-to on page 225 for help.*

Aim

To investigate how much friction different materials apply to a moving block

Materials

For each group:

- 1 m wooden board with a smooth finish
- 6 textbooks
- 5 × 10 × 10 cm block of wood
- stopwatch
- foil
- cotton cloth
- woollen cloth
- various other materials (if desired)
- cooking oil

Table INV8.5: Results

Material	Time 1 (s)	Time 2 (s)	Time 3 (s)	Average time (s)
Wood				
Foil				

Method

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Prop the wooden board up on some books to create a ramp.
3. Set the wooden block at the top of the ramp. Release the block and use the stopwatch to time how long it takes to slide down the ramp and hit the floor. Repeat two more times, then calculate the average time.
4. Cover the underside of the block with foil, then repeat step 3.
5. Cover the underside of the block with the cotton cloth, then repeat step 3.
6. Cover the underside of the block with the woollen cloth, then repeat step 3.
7. Cover the underside of the block with any other materials you want to check, then repeat step 3.
8. Cover the underside of the block with cooking oil, then repeat step 3.

Questions

1. Identify which material slowed the block down the most.
2. Identify which material slowed the block down the least.
3. Explain why the different materials affected the block's slide, referring to the effects of friction.
4. Propose a material that would have much more friction and much less friction than those you used in this investigation.
5. Identify whether the results support your hypothesis. If not, evaluate the validity of your hypothesis and the results, with reference to scientific theory and possible errors in the method.

Conclusion

Copy and complete:
'The results show that: (*respond to the aim*).'

Investigation 8.6

20 min

Measuring gravity

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Constructing graphs

Graphing data shows the relationship between factors.

Hint 1: *Identify the independent and dependent variables. Are they quantitative or qualitative?*

Hint 2: *What type of graph should be used for the data gathered in this investigation?*

Hint 3: *Refer to step 3 in 'Processing, modelling and analysing' in the Science how-to section on page 232.*

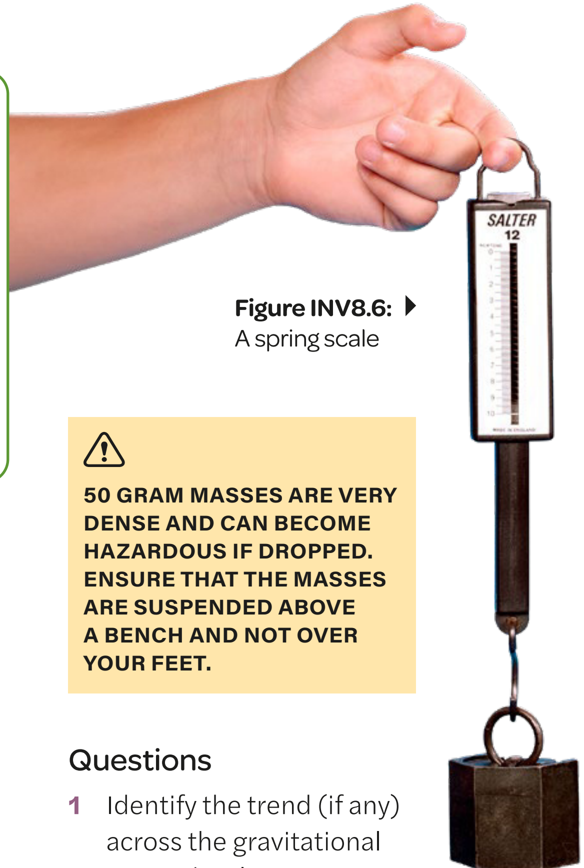


Figure INV8.6: A spring scale

50 GRAM MASSES ARE VERY DENSE AND CAN BECOME HAZARDOUS IF DROPPED. ENSURE THAT THE MASSES ARE SUSPENDED ABOVE A BENCH AND NOT OVER YOUR FEET.

Aim

To investigate the relationship between mass and weight, and how it relates to gravitational strength

Materials

For each group:

- 5 × 50 g masses
- 5 N spring scale
- mass hanger or carrier

Method

1 Copy the results table into your notebook, adding a title.

2 a Attach a 50 g mass to the bottom of the spring scale.

b Convert the mass into kilograms by dividing by 1000, e.g. (50 g)/1000 = 0.050 kg. Record the mass in kilograms (kg) in the results table.

c The reading on the spring scale shows the weight force of the mass (measured in Newtons (N)). Record the reading on the spring scale in the results table.

3 Repeat step 2, adding another 50 g mass each time, until there is a total mass of 250 g on the spring scale.

4 For each reading, calculate the strength of gravity by dividing the weight (N) by the mass (kg).

$$\text{Gravitational strength} = \frac{\text{weight (N)}}{\text{mass (kg)}}$$

5 Record the gravitational strength in the results table.

Questions

1 Identify the trend (if any) across the gravitational strength values.

2 Describe the ways you minimised risk for this investigation.

3 Describe how this investigation would be different if you conducted it on the Moon.

4 Construct a graph that shows the relationship between mass and weight from the data collected in your results table.

Conclusion

Copy and complete:

'The results show that: (*respond to the aim*).'

Table INV8.6: Results

Mass (kg)	Weight (N)	Gravitational strength

Investigation **8.7**

Crash cushions

Inquiry skill: Processing, modelling and analysing

Inquiry skill focus: Analysing processed data

When you conduct a formal investigation, the data should tell a story that leads to a key finding and addresses the aim. This becomes possible after you process the data into a graph and identify the trends and patterns. Analyse, or make sense of, the trends by linking them to scientific theory.

Hint: *Make sure your analysis of the data addresses the investigation aim or hypothesis.*

Aim

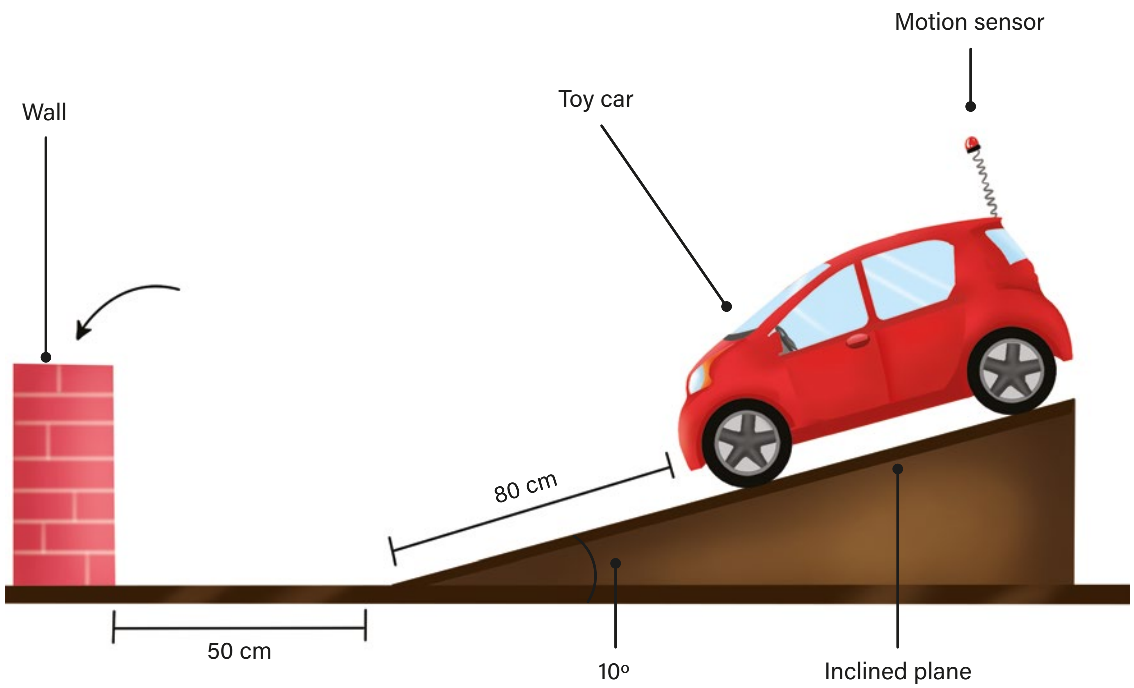
To investigate how different materials absorb the impact of forces

Materials

For each group:

- large toy car
- motion sensor that can measure force on impact (If this is not available, film the impact in slow motion and make observations based on the video footage.)
- inclined plane
- wall
- scissors
- tape
- construction paper, newspaper, cardboard boxes, straws, balloons, sponges, polystyrene and other materials

Figure INV8.7: For this investigation, set up the materials as shown in this diagram.



60 min

Method

1 Copy the results table into your notebook, adding a title and rows as needed.

2 If you have access to motion sensors, attach a sensor to the cart or car so that it measures the force of impact when the cart or car comes to a stop. If motion sensors are not available, set up a device to film the collision in slow motion.

3 Set up the inclined plane as shown.

4 Allow the cart or car to roll down the plane, collide with the wall and come to a stop. Read the impact measurement from the sensor or make written observations from the slow motion video. Record this data in your table as 'trial 1'. Repeat the trial and record the second measurement or observations.

5 Conduct at least three more trials. For each trial, create a 10 cm 'cushion' out of different materials, place it next to the wall and move the inclined plane back so there is a 50 cm space between the plane and the cushion. Allow the cart or car to roll down the plane, hit the cushion and come to a stop. Record the impact measurements or video observations in your table.

Table INV8.7: Results

Cushion material	Force of impact (N)	
	Trial 1	Trial 2
None		

Questions

1 Add an additional column to the results table and calculate the average force of impact for each cushion material. (For help with calculating averages, see the Science how-to section on page 265.)

2 Construct a column graph to represent the data visually.

3 Analyse the data:

a Which cushion was most effective at reducing the force of impact? Which was least effective?

b Identify any trends or patterns observed in the data. Were there any similarities between material types?

c Identify links between the trends and scientific theory about reducing the impact of forces.

4 Propose a key finding for this investigation that addresses the aim.

5 Propose and discuss ways in which cushioning materials could be used in cars to reduce the impact of a crash.

Conclusion

Copy and complete:
'The results show that: (*respond to the aim*).'

Investigation **8.8A**

30 min

Making a catapult

Inquiry skill: Evaluating

Inquiry skill focus: Identifying investigation errors and assumptions

Investigations in a school laboratory are never perfect. There are usually assumptions that are made, and unavoidable errors in the method that impact the results and must be acknowledged. What assumptions and errors are present in this investigation?

Hint 1: *Are we assuming that all materials, like popsicle sticks, are identical?*

Hint 2: *Refer to step 1 of 'Evaluating' in the Science how-to section on page 239.*

Aim

To investigate the types of levers involved in loading and firing a catapult

Materials

For each group:

- 7 popsicle sticks
- 4 rubber bands
- small polystyrene ball
- metre ruler (or a tape measure)

Method

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Form a stack of five popsicle sticks and wrap a rubber band around each end to hold them together.
3. Stack the other two popsicle sticks and bind them together at one end using another rubber band.
4. Separate the two popsicle sticks at the end without the rubber band and slide the stack of five in between the two sticks. The upper stick should make an angle of about 25 degrees with the horizontal.
5. Wrap the final rubber band around the centre of the structure to hold it all together.
6. Place a polystyrene ball on the raised end of the sloping stick. Launch the ball by pressing down and releasing the stick.
7. Measure the distance travelled by the polystyrene ball and record this information in the results table. Repeat this several times.

Questions

1. Identify the forces acting in this catapult.
2. Describe the type of lever that is being used.
3. a Explain what changes you would make to the catapult if you wanted to make the polystyrene ball travel further.
   b Propose how assumptions or errors in this investigation could affect your ability to replicate or improve the method.
4. Propose a scenario where this type of lever might be useful in helping to solve a problem.
5. Sometimes, we may need a catapult to launch an object higher or faster. Propose three ways you would alter the design of the catapult to allow for this.

Table INV8.8A: Results

Attempt number	Distance travelled

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

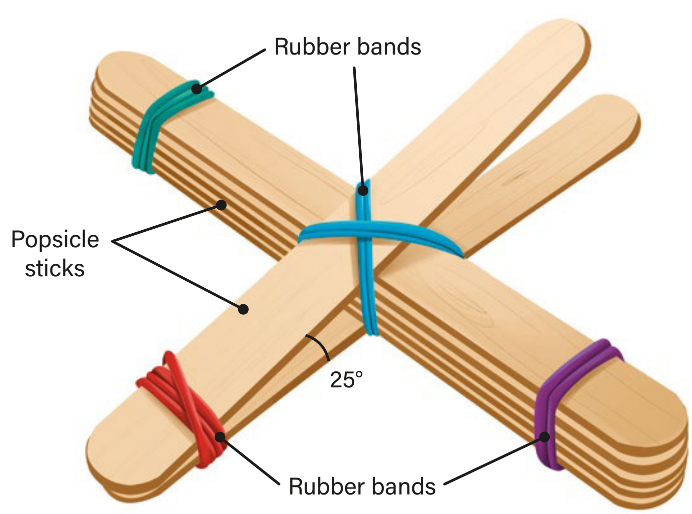


Figure INV8.8A: For this investigation, set up your catapult as shown in this diagram.

Investigation **8.8B**

30 min

Using ramps

Inquiry skill: Evaluating

Inquiry skill focus: Constructing evidence-based arguments

The results of an investigation can be used as evidence to make claims and construct arguments about scientific strategies. How might the results of this investigation be used to make recommendations about using inclined planes?

Hint: *How does using inclined planes impact the effort required to do work?*

Figure INV8.8B: For this investigation, set up the materials as shown in this diagram.

Aim

To measure the force required to lift a block vertically and to lift it using ramps of different slopes

Materials

For each group:

- spring scale
- string
- smooth block of wood (10 cm by 10 cm) with a hook screwed into one end
- 6 textbooks (or a retort stand and clamp)
- smooth, flat board (10 cm wide, 50–100 cm long)
- metre ruler
- protractor

Method

1. Copy the results table into your notebook, adding a title and rows as needed.
2. Use a loop of string to tie the spring scale to the block of wood.
3. Let the block hang freely. Lift the block from the desktop to the height of the stack of three books. As you lift, note the force recorded on the spring scale. Record that force.
4. Record the height, in metres, from the desk to the top of the stack of books.
5. Incline the board from the desk to the top of a stack of three books.
6. Place the block of wood at the bottom of the ramp.
7. Pull the block of wood up the ramp slowly. As you do this, note the force reading on the spring scale. Record the effort used.
8. Add another three books to the stack. This will put the ramp at a different angle. Repeat Steps 3–7. Record your results in the table.

Questions

1. In each trial, how does the force used to slide the block up the inclined plane compare with the force needed to lift the block to the same height?
2. Describe the effect that increasing the angle of the ramp has on the force needed to slide the block up the ramp. Justify your answer.
3. Suggest changes you could make to improve this machine.
4. List three situations in which using a ramp is useful.
5. Use the results of this investigation to construct an evidence-based argument in favour of using inclined planes rather than directly lifting a load.

Table INV8.8B: Results

Angle of ramp (°)	Distance along ramp (cm)	Effort to pull trolley up ramp (N)
0		

Conclusion

Copy and complete:

'The results show that: *(respond to the aim)*.'

Investigation 8.8C

40 min

Modelling a seesaw

Inquiry skill: Evaluating

Inquiry skill focus: Describing types of errors

Investigations in a school laboratory are never perfect. There are often errors in the method or equipment that impact the results and must be identified. Acknowledging and describing various types of errors helps to evaluate the reliability of your results and suggest improvements for future investigations. (See step 2 of 'Evaluating' in the Science how-to section on page 241.)

Hint 1: *Are there systematic errors in the equipment or setup that consistently affect the results?*

Hint 2: *Are there random errors, such as variations in measurements or environmental factors, that make the results less consistent?*

Hint 3: *Could human error, such as reading instruments incorrectly or inconsistencies in technique, have affected the investigation?*

Aim

To investigate factors that balance a seesaw

Materials

For each group:

- hanger clamps
- retort stand and clamp
- masking tape
- 200 g mass
- metre stick
- 4 × 25 g masses
- 100 g mass
- 500 g mass

Method

1 Copy the results table into your notebook, adding a title.

2 Using a hanger clamp, attach a metre stick so it hangs, balanced, from a clamp on a retort stand (see Figure INV8.8C). This is the fulcrum of the lever.

3 Tape two 25 g masses 40 cm from the balance point of the stick. This is the load force.

4 Hang two 25 g masses as a counterweight from the other end of the stick. Move the counterweight until the stick is balanced. This is the effort force.

5 In the results table, record the distance from the centre of the metre stick to the position where the mass balances the metre stick.

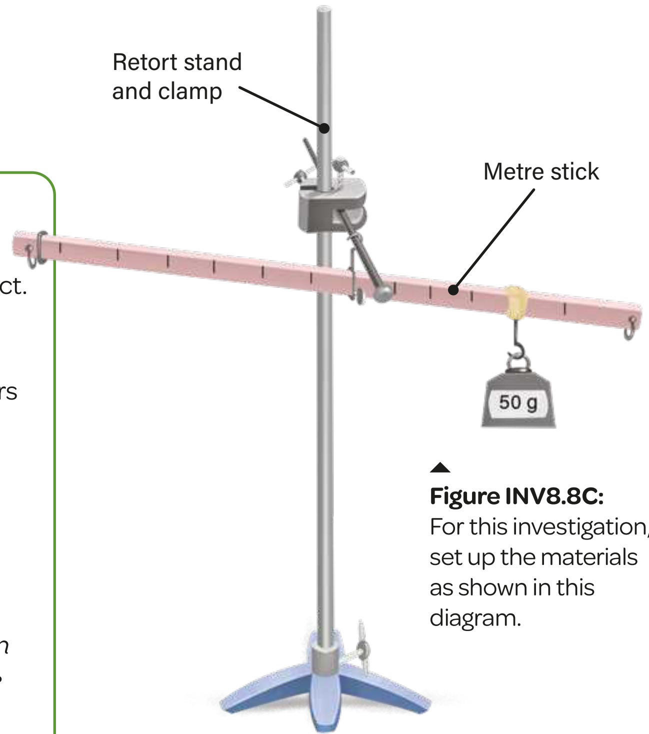


Figure INV8.8C: For this investigation, set up the materials as shown in this diagram.

6 Remove the hanging counterweight. Repeat steps 4 and 5, replacing the counterweight with a 100 g mass, a 200 g mass and a 500 g mass. Record your results in the table.

Questions

1 Construct a labelled force diagram to represent the forces that are acting in this model of a seesaw.

2 Describe the effect that increasing the mass of the counterweight (effort force) had on how close it needed to be to the fulcrum.

3 In your experience or observations, have you ever had to adjust the positions of people sitting on a seesaw to make it balanced? If so, describe this experience, with reference to forces.

Table INV8.8C: Results

Mass (g)	Distance from fulcrum (cm)
50	
100	
200	
500	

Conclusion

Copy and complete:

'The results show that: *(respond to the aim).*'

Investigation 8.8D

40 min

Pulley investigation

Inquiry skill: Evaluating

Inquiry skill focus: Supporting findings with evidence

The results obtained in an investigation should always be explained in the discussion of a scientific report using scientific knowledge (see the Science how-to on page 250).

Hint 1: *Think about the scientific concepts that are important for the investigation.*

Hint 2: *Summarise the data and any trends shown in your results.*

Hint 3: *Explain the data and trends using scientific understanding. For example: 'The results showed that ... This is because ...'*

Aim

To determine how to use a pulley to lift a load

Materials

For each group:

- block of wood (10 cm by 10 cm) with a hook screwed into one end
- metre ruler or board, with two hooks, one on either side of the centre (or 2 retort stands and clamps)
- 3 pulleys with hooks
- 1 N spring scale
- 2 pieces of heavy string or butcher cord (1.5 m and 3 m)

Method

1 Copy the results table into your notebook, adding a title and as many rows as needed.

Part 1

2 Hang the block of wood from the spring scale. In the results table, record the force required to suspend the wood.

3 Support the board between two desks, as shown in Figure INV8.8Da. Hang a pulley from one of the hooks on the board. Put the block of wood on the floor under the pulley. String the cord through the pulley and tie it to the block of wood.

4 Mark the cord at the point where it exits the pulley.

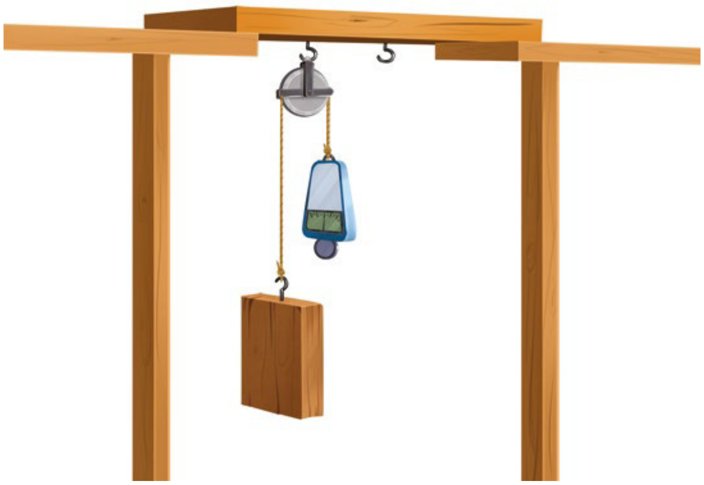


Figure INV8.8Da: Pulley set-up for Part 1

5 Tie a loop in the loose end of the cord. Hook the scale to the loop. Gently pull down on the scale until the block of wood rises slowly.

6 Record the reading on the scale.

7 Keep pulling until the block is 10 cm off the floor. Mark the string at the point where it now exits the pulley. Record how far the string was pulled.

Part 2

8 Attach a pulley to the hook just to the right of the centre of the board.

9 Attach the block of wood onto a second pulley using the hook on the end of the block.

10 Tie the cord to the hook just to the left of the centre of the board. String the cord down through the pulley attached to the block of wood, then up and through the fixed pulley on the board, and then back towards the floor (see Figure INV8.8Db).

11 Mark the cord at the point where it exits the pulley system.

12 Hook the scale to the loop on the free end of the string. Gently pull down on the scale until the block of wood rises.

13 As the block rises, record the reading on the scale.

14 Measure and record how far the cord is pulled down to raise the block 10 cm.

continues ▶

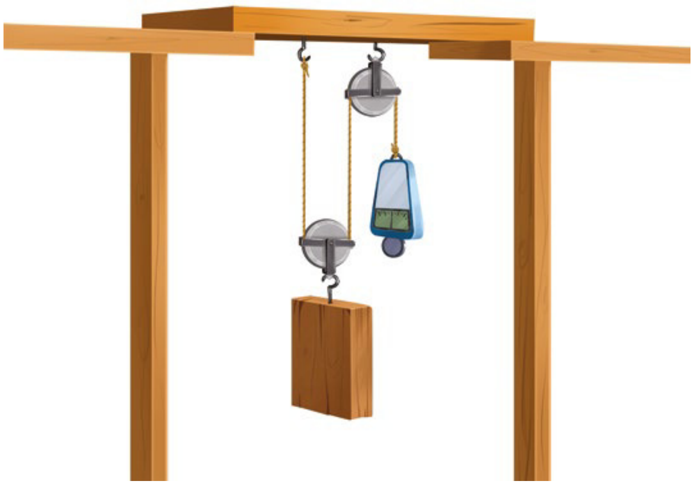


Figure INV8.8Db: Pulley set-up for Part 2

Part 3

15 Attach a pulley to each of the hooks on the board.

16 Attach a pulley to the top of the block of wood.

17 Run the string from the top of the pulley attached to the block of wood, up through the pulley on the left, back down and through the lower pulley, and then up and through the second pulley on the right. Run the loose end down towards the floor. See Figure INV8.8Dc.

18 Repeat steps 11–14.

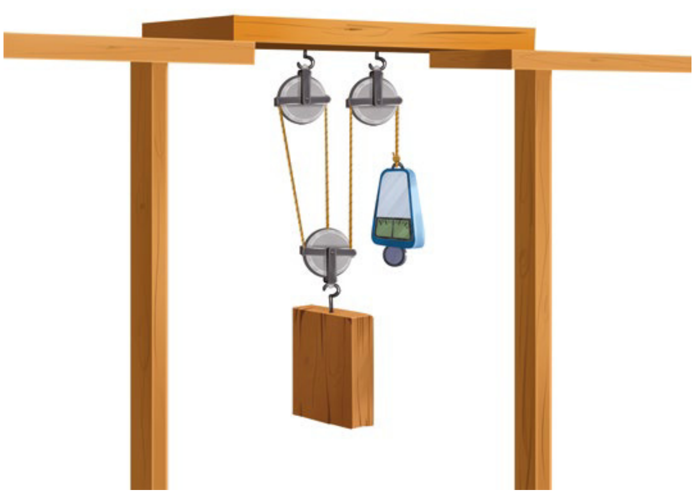


Figure INV8.8Dc: Pulley set-up for Part 3

Questions

1 Determine which pulley set-up required the most effort to lift the block of wood. Explain why.

2 Determine which pulley set-up required the least effort to lift the block of wood. Explain why.

3 Determine the difference between the distances the cord was pulled in Parts 1, 2 and 3.

4 Propose which pulley system you would recommend to lift a load at a shipping dock. Justify your choice.

Table INV8.8D: Results

Pulley system	Force applied to lift wood (N)	Distance cord was pulled (cm)
1		
2		
3		

Conclusion

Copy and complete:
'The results show that: *(respond to the aim)*.'

Glossary

A

abiotic: non-living

accuracy: how close a measured value is to the true, exact value; how closely a recorded value matches the expected outcome of an investigation

adaptation: a characteristic that an organism is born with that helps it to survive in its environment

agriculture: the science or practice of farming

Ancestors: the people we are descended from

angiosperm: a plant that produces seeds in fruit or flowers

annular: ring-shaped

anomalies: data points or findings that do not follow the normal trend or expected findings

applied force: a force that is applied to an object by a person or another object

aqueous solution: a solute dissolved in water

astronomer: a scientist who studies space and the objects within it

astronomical unit (AU): a unit of measurement that is equal to the average distance between Earth and the Sun – 147 million kilometres

atmospheric nitrogen: nitrogen in the atmosphere

axis: a real or imaginary line through the centre of an object

axle: the pin, shaft or rod that a wheel can spin around to transfer force

B

balanced force: net force is equal to zero

biodiversity: the variety of organisms in an ecosystem

Biological Sciences: the science of living things

bioplastics: plastics produced from plant materials, such as vegetable oils, starch and wood chips

biotic: living

boiling point: the temperature at which a liquid vigorously changes to a gas

branch: a type of science, such as biology or chemistry

brumation: the state of dormancy (inactivity) reptiles undergo in winter (similar to hibernation)

bryophyte: a plant that does not contain vascular tissue

Bunsen burner: a piece of scientific equipment that produces a single open gas flame

C

carbon dioxide: a colourless and odourless gas containing carbon and oxygen that is produced during respiration

centrifugation: a technique for separating the components of a mixture on the basis of their different densities

chemical bond: a force that holds atoms together

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

Chemical Sciences: the science of chemicals and matter

classification: the process of sorting things into groups or classes

classification key: a tool to help classify an organism by identifying important characteristics such as its features and behaviours

coefficient of friction: a value that indicates how easily an object moves when interacting with another material

collaboration: working cooperatively with other people to complete a task or solve a problem

colloid: a mixture made of tiny insoluble particles that remain dispersed evenly in a liquid

community: a naturally occurring group of animals, plants and other organisms

compound: a substance containing atoms of two or more elements chemically bonded together in a fixed ratio

compress: squash something into a smaller shape

concave: hollowed or rounded inwards

concentrated: when a solution has a large amount of solute in a certain volume

concentration: the amount of a dissolved solute in a defined amount of solvent; the number of particles in a given space; particles crowded in one place is high concentration

condensation: a change of state from gas to liquid

condense: the process of changing state from gas to liquid

condenser: a glass tube cooled by water that cools a gas to become a liquid

consumer: an organism that gains energy by consuming other living organisms

controlled variable: variable in an investigation that must be kept the same for all trials. Only the independent variable should change, otherwise it is not a fair test

conversion factor: a number used to change one unit of measurement to another

coolamon: a shallow dish traditionally used by First Nations Peoples to carry water and food and for winnowing seeds

correlation: a relationship between two factors or variables that shows them changing together, in either the same or opposite way

Country: the physical environment with which a particular Aboriginal and Torres Strait Islander Peoples group has a deep and reciprocal relationship. One both owns and is owned by one's Country, which includes lands, waters and sky

crude oil: oil that has not been separated into usable petroleum products

crystallisation: the separation of a solution by evaporating the solvent, leaving behind solute crystals

cultivation: preparing and using land for crops or gardening

culture: a shared system of customs, habits, beliefs/spirituality, social organisation and ways of life that characterise different groups and communities

D

data: facts and information collected for reference or analysis

data point (datum): a single identified element in a dataset

dataset: a collection of data, often from numerous trials related to a single factor

decantation: the process of carefully pouring off the liquid from a mixture, leaving the sediment behind

decomposer: an organism that breaks down and recycles decaying matter

deforestation: the removal of trees to make land available for other uses

deform: to change shape

density: how heavy something is for its size; mass divided by volume

density formula: $d = \frac{m}{V}$ (unit: g/mL^3)

dependent variable: the thing that is measured in a first-hand investigation

deposition: the process of changing state from gas to solid without going through the liquid state

desalination: the process of removing dissolved salts from seawater

dichotomous: divided into two parts

diffuse: when light becomes spread out as it passes through the atmosphere

diffusion: the movement of particles from areas with more particles to areas with fewer particles

dilute: when a solution has a small amount of solute in a certain volume

direct force: a force that acts on an object when in contact with another object; also known as contact force

disinfection: a method of destroying bacteria, often using special light or chlorine

dissipate: remove or cause to disappear

dissolve: particles separating and spreading out, so that they seem to disappear, when added to another substance

distillation: the separation of liquids with different boiling points by evaporation and condensation

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: important stories for First Nations Peoples; these stories often contain important knowledge of the world

E

Earth and Space Sciences: the study of Earth's dynamic structure and Earth's place in the universe

eclipse: the blocking of the Sun's light from Earth

ecosystem: a community of living things interacting with one another and the non-living things in their environment

effort: the force applied to a simple machine to move another object

Elder: a First Nations person who is a recognised custodian of knowledge, who has permission to pass on that knowledge, and who has specific responsibilities to young people in a community

element: a substance made of only one type of atom

endangered: at risk of becoming extinct

endeavour: to try to do something

endemic: only found in a certain location or community

energy: the ability to do work

energy pyramid: a model that shows the flow of energy from one trophic level to the next

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

equinox: the two times each year when night and day are about the same length

ethical: in science, minimising harm to those involved, and ensuring investigations are conducted honestly and data is collected and recorded accurately

ethics: moral principles that impact how a person behaves; understandings of what is wrong or right

evaluate: judge value based on scientific evidence

evaporation: a change of state from liquid to gas; the separation of a solid from a solution by heating to remove the liquid

evidence: facts and information that give reason to believe that something is true

experiment: a test done in order to learn something or to discover if something is true

exploration: processes undertaken to find rocks that contain minerals

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

extinct: having no living members of the species; died out

F

fair test: a test where all variables are kept the same, except for the independent variable and the dependent variable

fauna: animals

field: an area of space where objects are affected by an indirect force

filtrate: the liquid that passes through a filter in filtration

filtration: the process of separating a mixture of solid particles from a liquid by using a filter

finite: limited in size or amount

flora: plants and microorganisms

food chain: a path of energy through an ecosystem

food web: a system of interlocking food chains

force: a push, pull or twist on an object when it interacts with another object

force diagram: a simplified diagram showing the direction and size of forces acting on an object

form: what something is made up of

fossil fuel: a natural fuel formed over millions of years from the remains of living things

freeze: change state from liquid to solid

friction: a force between two surfaces that are sliding, or trying to slide, across each other; a force that resists the motion of an object

fulcrum: the point on which a lever turns when moving an object

function: the way something works

G

galaxy: a large system of stars

gas: the state of matter where the substance expands or contracts to fit the shape and volume of its container

gas pressure: force of gas particles on the walls of their container

geocentric model: a model of the solar system with Earth at the centre

germination: the process in which previously dormant seeds put out shoots for new growth

gravitational force: an indirect force that attracts physical objects with mass towards each other

gravity: the force of attraction between two objects

grinding: the action of rubbing objects together to break up materials into smaller particles

gymnosperm: a plant that produces seeds in cones

H

habitat: the place where an animal or a plant naturally lives

hand picking: a simple method of separating a mixture of objects

hazard: something that can harm living things, objects or the environment

heat: a type of kinetic energy that is transferred between things

heating flame: the blue (very hot) flame of a Bunsen burner (approx. 1500 °C); used for heating substances)

heliocentric model: a model of the solar system with the Sun at the centre

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

homogeneous: a mixture in which one substance (the solute) is uniformly dissolved in another, resulting in a uniform composition

hydropower: electricity generated by flowing water turning a turbine

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

I

immiscible: cannot form a homogeneous mixture; insoluble

impact: the effect of a force

incline: a surface with an upward slope

inclined plane: a sloping or tilted flat surface; also called a ramp

independent variable: the thing that is deliberately changed in a first-hand investigation

indirect force: a force that acts on an object without the need for physical contact; also known as non-contact force

inference: a conclusion that is based on evidence and observations

infinite: never runs out

insoluble: does not dissolve

intensity: how much heat is released from a fire front

interact: for objects to act upon or have an effect upon each other

invertebrate: an organism without a backbone or spinal cord

irrigation: supplying water to land or crops

K

kinetic energy: energy in the form of motion

kinetic friction: a friction force that acts in the opposite direction to the motion of an object

kinetic theory: a model used to explain the behaviour of matter in terms of the energy and motion of particles

knapping: the action of applying force to a specific type of rock to create a sharp shard

L

landfill: disposal of waste by burying it

lattice: a three-dimensional shape made of a repeating pattern of atoms

leaching: a method of removing soluble substances by the action of water passing through the material

lever: a bar acted upon at different points by two forces

leverage: the action of a lever

lightyear (ly): The distance light travels in one Earth year – 9 trillion kilometres

liquid: the state of matter where the substance takes the shape of its container but has a fixed volume

living thing: an organism that displays specific characteristics of being alive

load: an object that is moved or lifted by a simple machine

load force: the force from the object that is being moved

lubrication: a substance that makes a surface slippery or smooth

M

made resource: a resource that is manufactured from natural resources

magnetic separation: a process that uses magnets to separate magnetic materials from non-magnetic ones in a mixture

magnitude: the size or power of an object, energy or force

mass: the amount of matter an object or physical body contains

mathematical formula: a rule or principle that helps you to find the answer to a question or understand the relationship between variables

matter: any substance that has mass and takes up space

mean: a measure of centre (an average) calculated by adding all the numbers together and dividing by how many numbers there are

median: the middle number in a set of numbers when they are arranged in order

melt: change state from solid to liquid

melting point: the temperature at which something changes from a solid to a liquid

meniscus: the curve seen at the top of a liquid in a container

metallurgy: the science of metals

mineral deposit: rocks that contain a particular mineral

mixture: a combination of two or more elements and/or compounds that can be separated

mode: the number that appears most frequently in a set of numbers

model: a physical or mathematical representation of a scientific idea or concept

monoculture: the practice of cultivating a single crop in a given area

multidisciplinary: combining or involving more than one scientific branch of knowledge

mutualism: a relationship between two organisms in which both organisms benefit

N

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

naturalist: someone who studies nature and its history

net force: the sum of all forces acting on an object

newton (N): the unit for measuring force; SI unit N

nocturnal: active during the night

non-biodegradable: does not break down in the environment

non-renewable: finite, and will run out

normal force: the force that acts from a surface pushing against an object

O

observation: noticing something you can see, touch, smell, hear or taste, and know to be true

oil slick: a thin layer of oil on the surface of water

orbit: the path of an object around a star or planet; for example, Earth around the Sun, or the Moon around Earth

ore body: a mineral deposit that is profitable to mine

organism: an individual animal, plant or other living thing

P

paper chromatography: a technique that separates the components of a mixture based on their solubilities

parallax error: the apparent shift in something's position when it is viewed from different angles

parasite: an organism that lives in or on another organism, causing it harm

particle: a very small amount of matter

particle theory: a model used to explain the structure and properties of matter

pattern (data): when data repeats in a predictable way

pendulum: a mass that is attached to a fixed point by a string and can move backwards and forwards freely

Penicillin: a drug that fights bacterial infections

penumbra: the outer part of the Moon's shadow on Earth

pesticide: a chemical used to kill insects or other organisms that feed on plants

phenomenon (plural **phenomena**)**:** an observable fact or event

Physical Sciences: the science of matter and energy

pivot: to turn around a single point or fulcrum

plagiarise: to copy someone else's work and present it as your own

plausible: could be reasonably accepted based on available evidence

pollinator: an organism that transfers pollen from the male part of a plant to the female part

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

precision: how close measured values are to each other within a dataset

predator: an organism that kills and feeds on prey

pressure: the force applied by gas particles hitting the sides of their container

prey: an organism that is killed by a predator

producer: an organism that makes its own food using energy from the Sun

pulley: a wheel with a grooved rim for carrying a cable

Q

qualitative data: data with qualities or characteristics that can be observed and described

quantify: to measure the size or amount of something

quantitative data: data that can be counted, measured or represented by numbers

R

range: in a set of numbers, a measure of spread between the highest number and the lowest number

ratio: a way of comparing like quantities without units

raw data: data that is collected directly from the investigation

recycling: converting waste into reusable materials

rehabilitation: processes that return the environment to close to how it was before mining

relationship: a link between two factors

renewable: can be renewed, and will not run out

repeatable: provides consistent results when repeated

research proposal: a document setting out details of all aspects of a planned scientific investigation. Members of an ethics committee review it to ensure it conforms to the principles of good and safe science

residue: the solid that does not pass through a filter in filtration

resistive forces: forces that oppose the motion of an object)

resource: a source of something that is useful

respiration: a chemical reaction that converts glucose to energy

revolve: move in a circular path around another object

risk: the chance that a hazard will cause harm

rotate: spin on an axis

rotation: turning around as if on an axis

Rube Goldberg machine: a machine or contraption that uses a chain reaction, usually to carry out a simple task

S

safety flame: the orange (cooler) flame of a Bunsen burner (approx. 300 °C); used between heating substances

satellite: an object that orbits a planet; Earth has a natural satellite called the Moon plus many purpose-built artificial satellites

saturated: a solution that cannot dissolve any more solute

saturation point: the point at which a solution has dissolved the maximum amount of solute

scale: the relationship between the sizes of two things

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

sediment: small particles of rocks, such as clay, sand and pebbles; the solid that settles to the bottom of a liquid in a mixture

selective breeding: breeding organisms with desirable traits

sewage: semi-liquid human waste

sewerage: a system of pipes that carry sewage

sieve: a tool with small holes used to separate solids from liquids

sieving: using a sieve to separate larger particles from smaller particles

sky Country: in First Nations knowledge, the aspects of Country that are not linked to the land; all the observable celestial phenomena and the spirits and lore linked to these events

socio-scientific issue: an issue where science impacts on society, and may involve economic, environmental, ethical and social considerations

solar energy: heat and light energy from the Sun

solid: the state of matter where the substance has a fixed shape and volume

solstice: the two times each year when night and day are the most different in length

solubility: the amount of solute that will dissolve in a solvent

soluble: able to dissolve

solute: a substance that is dissolved by a solvent solution (a mixture made up of a solvent and a solute)

solution: a homogeneous mixture in which one substance (the solute) is uniformly dissolved in another

solvent: a substance that a solute dissolves in

songlines or song series: complex ways that First Nations Peoples record important information relating to many different topics; a body of songs sung sequentially, and which are intended to convey knowledge

species: a single, specific type of living thing

spirits: the supernatural beings that many First Nations Peoples believe exist; can be associated with particular places, objects and rituals; are often connected with Dreaming stories

spore: a tiny part of some plants that is used to reproduce

stable: remains the same; does not change

static friction: a friction force that keeps an object in place on a surface

stationary: not moving or changing position

stimuli: changes in the environment that cause responses in living things

structure: the construction and arrangement of tissues, parts or organs

sublimation: the process of changing state from solid to gas without going through the liquid state

subscript: a letter or number written slightly below and to one side of another; for example, '2' in H_2O

supersaturated: when a solution contains more than the maximum amount of solute it can normally dissolve

superscript: a letter or number written slightly above and to one side of another; for example, '2' in 8^2

surface tension: where the molecules at the surface of a liquid are more attracted to each other than to the air above the liquid

suspension: a mixture made of large insoluble particles that settle to the bottom of the liquid

sustainable: supporting present needs without compromising the ability of future generations to support their needs

system: a set of simple things that work together to perform a function

T

taxonomy: the science of classifying organisms

temperature: a measurement of the average kinetic energy of particles in an object

tension: a pulling force exerted by each end of an object

thermal contraction: the effect of becoming smaller (shrinking) due to the removal of heat

thermal expansion: the effect of becoming bigger (increasing in size) due to the application of heat

threatened: likely to become endangered in the near future

thrust: the force that pushes an object forward

tide: the rise and fall of the waters in the ocean, caused by forces from the Moon and the Sun

tilt: a sloping position or lean

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

toxin: a poisonous substance produced by a living thing

tracheophyte: a plant that contains vascular tissue

transdisciplinary: collaboratively working across multiple branches to learn or solve problems

transfer: to move from one place to another

trend (data): when data moves in a general direction, usually up or down

trophic level: the position of an organism in a food chain

true value: the actual, exact value of a measurement, error-free, which would be obtained if a perfect measurement were obtained

tuber: the rhizome part of a plant, which forms underground and is often nutrient rich

U

umbra: the inner part of the Moon's shadow on Earth

unbalanced force: net force is not equal to zero

underpin: the starting point from which ideas develop

understorey: ground-level vegetation

universal solvent: a solvent that dissolves most substances

urbanisation: the creation of urban areas such as cities

V

validity: when an investigation meets its intended purpose

variable: a factor in an investigation or a model that can be changed, measured or controlled

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

vertebrate: an organism with a backbone or spinal cord

viscosity: how easily a liquid can flow

volume: the amount of space an object takes up

W

waning: when the Moon looks as though it is getting smaller

waxing: when the Moon looks as though it is getting bigger

weight: the force of a gravitational field on the mass of a body

winnowing: separating a mixture of seeds and husks by blowing air through the mixture

Y

yandying: separating less dense particles from denser ones

yield: the amount of something that is harvested

Z

zone of tolerance: the range of an abiotic factor that an organism can survive in

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